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CSI Resource Systems, Inc.
Boston, MA

Prepared for

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Predicated upon a Phase I site visit and scope development to the City of Aiken, this Phase II study was performed with the following objectives: 1) evaluation of increasing the usable life of landfills; 2) assess alternatives for disposal; 3) evaluate central baling/transfer facility against direct haul; 4) assess new methods of manure and leaf disposal; 5) perform market for recyclables; 6) define costs productive methods for improved refuse collection. This document addresses extending the life of landfill, future disposal alternatives, manure and leaf disposal, materials recovery, and solid waste collection.

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A TECHNICAL ASSISTANCE PROGRAM REPORT

CITY OF AIKEN, SOUTH CAROLINA

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RESOURCE RECOVERY AND CONSERVATION PANELS

SEC. 2003. The Administrator shall provide teams of personnel, including Federal, State, and local employees or contractors (hereinafter referred to as "Resource Conservation and Recovery Panels") to provide States and local governments upon request with technical assistance on solid waste management, resource recovery, and resource conservation. Such teams shall include technical, marketing, financial, and institutional specialists, and the services of such teams shall be provided without charge to States or local governments.

This report has been reviewed by the Project Officer, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Project Officer: Elmer G. Cleveland

U.S. ENVIRONMENTAL PROTECTION AGENCY

TECHNICAL ASSISTANCE PROGRAM REPORT SERIES

TECHNICAL ASSISTANCE TO THE CITY OF AIKEN, SOUTH CAROLINA

PREPARED FOR

OFFICE OF SOLID WASTE MANAGEMENT

U.S. ENVIRONMENTAL PROTECTION AGENCY

REGION IV, ATLANTA, GEORGIA

BY

ENGINEERING-SCIENCE, INC.

ATLANTA, GEORGIA

AND

CSI RESOURCE SYSTEMS, INC.

BOSTON, MASSACHUSETTS

DECEMBER, 1980

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CHAPTER 1
SUMMARY AND CONCLUSIONS

Aiken, a city of approximately 15,000 persons, is located in the southwest part of South Carolina and is the county seat of Aiken County.

The City of Aiken submitted a request for technical assistance to the U.S. Environmental Protection Agency (EPA) in the area of solid waste management. Based on the needs expressed during the Phase I project (site visit and scope development) the following general objectives were defined for the Phase II study:

- o Perform technical evaluation of alternatives for increasing the usable life of the present landfill property.
- o Assess alternatives for disposal when the present landfill site has been totally utilized.
- o Assess the feasibility of a central baling/transfer facility versus direct haul.
- o Assess alternatives for the disposal of manure and leaf wastes.
- o Perform a preliminary market assessment for recovered materials.
- o Evaluate the City's refuse collection systems and define methods for improving productivity and cost efficiency.

The following section of this chapter summarizes the information collected during the study. The final section presents major conclusions which were developed. The details of the study are presented in the subsequent chapters of the report.

SUMMARY

Present Landfill

The City of Aiken presently disposes of its solid waste in a landfill which is located within the city limits. The landfill is sited on a City-owned parcel of property encompassing approximately 67 acres. About 44 acres of the property are presently permitted for waste disposal by the South Carolina Department of Health and Environmental Control (SCDHEC). The remaining 23 acres are not currently permitted but were at one time. The permitted area is used for landfilling of refuse as well as open (uncovered) disposal of yard and gardening wastes, white goods (appliances), tires and animal manure. Portions of the non-permitted area have been used for open burning and landfilling in past years. It is estimated that the landfill has a remaining life of about 7 to 8 years using present operating methods (see Estimate 1, Appendix D).

The method presently in use at the Aiken City landfill is a combination of the classic trench and ramp methods. Waste placement and compaction and cover placement and compaction are done with a crawler-type loader. Major excavation is required approximately once per year and has been done in the past by a private contractor using a scraper.

Extending the Usable Life of the Present Landfill

During the course of the study several methods for extending the usable life of the Aiken City landfill were defined and can be categorized as follows:

- Increased area utilization efficiency resulting from alternative landfilling method (e.g., more efficient cell structure).
- Increased area utilization efficiency resulting from alternative landfill equipment usage (e.g., landfill compactor).
- Further use of under-utilized portions of the permitted landfill property (e.g., additional filling to higher final grade).
- Re-permitting and use of the non-permitted portion of the landfill property.

These alternatives are discussed in Chapter 2. Based on an evaluation of the alternatives, each was given a qualitative rating as to its technical potential for success. These ratings are summarized in Table 1.1.

An estimate was performed of the maximum possible life expectancy of the Aiken landfill using the viable life extending concepts defined during this study (see Estimate 2, Appendix D). These concepts are as follows:

- o Increased volume utilization efficiency due to improved cell structure.
- o Increased area utilization efficiency as a result of filling to a higher final elevation.
- o Additional filling on top of previously filled area.
- o Re-permitting and filling in area which was used only for burining in the past.

It was estimated that the remaining usable life of the landfill could be increased to as much as 15 to 16 years if the viable concepts are fully utilized.

The economic benefits, from the adoption of procedures which would extend the life of the present landfill, would occur in the following areas:

- o Decreased annual landfill costs due to a slower land utilization rate.
- o Deferment of the costs for development of a new landfill site.

The reduction in annual costs from a lower land utilization rate would amount to a relatively small percentage of the total annual operating cost (estimate 2% to 3%). However, the deferment of the significant capitol costs which would be required to develop a new landfill site could make extending the life of the present landfill economically attractive.

Future Disposal Alternatives

Three basic methods for future municipal solid waste disposal were defined for the City of Aiken. These are as follows:

- o Continued sanitary landfilling
- o Incineration
- o Composting

TABLE 1.1

SUMMARY OF CONCEPTS FOR EXTENDING USABLE
LIFE OF AIKEN LANDFILL PROPERTY

General Concept	Potential for Success[1]		Further Study Required to Establish Technical Viability
	Good	Poor	
Improved landfill methods	X		
Alternate equipment usage		X	
Further use of under-utilized portions of landfill property:[2]			
Presently permitted area	X		X
Presently non-permitted area	X		X

(1) Refers to technical potential for extending present landfill service life. Major economic benefits would be from the defermant of development costs for a new landfill.

(2) Refers to portions of property which are not presently being landfilled and are not in the area where future landfilling is currently planned.

Continued sanitary landfilling is believed to be the most economically attractive of these three alternatives.

Once the present landfill is closed, the City will have the option of (1) establishing a new City landfill or (2) disposing of waste in the Aiken County landfill. If a new City landfill is constructed, significant initial capital costs and annual operating and maintenance (O&M) costs will be incurred. It is possible that a new City landfill would be located near Aiken and the cost of hauling refuse to the landfill would be minimized. At present, the County landfill is operated using money from county property taxes (of which the city of Aiken residents pay a share) so no additional capital or O&M costs would have to be paid by the City of Aiken for use of the County landfill. The County landfill, however, is located about 12 road miles from Aiken and the cost associated with hauling waste there could be significant.

Table 1.2 tabulates information concerning the relative economics between the available refuse hauling (transfer or direct) and landfill options. Based on these cost estimates, it is more economical to haul refuse to the County landfill than to continue using the City landfill or develop a new City landfill. A possible course of action for the near future is to close the active portion of the City landfill and use the County landfill. This would reduce the City's refuse disposal costs and, if the permit can be maintained, would provide some back-up landfill capacity if circumstances change and it becomes attractive to reopen the City landfill.

Manure and Leaf Disposal

The City-owned and private landscaped areas in Aiken yield a large quantity of waste leaves. Four horse tracks and a number of stables within the town also result in a considerable amount of stable wastes (manure, etc.). Currently most of the waste manure and leaves are placed in uncovered piles on the City landfill property. City of Aiken personnel believe that leaves and manure pose a significant disposal problem for the City.

TABLE 1.2

RELATIVE ECONOMICS OF LANDFILL DISPOSAL OPTIONS

Disposal Option	Estimated Disposal Cost ($/ton)(1)	Approximate Average Haul Distance (miles)	Estimated Haul Cost ($/ton)(1)	Haul and Disposal Cost ($/ton)(1)
Aiken City Landfill				
Present Site	9.5(2)	2.3	1.2(4)	10.7
North Site	9.5(2)	3.3	1.7(4)	11.2
West Site	9.5(2)	4.0	2.0(4)	11.5
Aiken County Landfill				
Haul with packer vehicle	0(3)	12	6.0(4)	6.0
Haul with transfer vehicle	0(3)	12	9.4(5)	9.4

(1) All costs expressed in terms of 1980 $.

(2) See Table 3.1 and Appendix B for cost estimates. Assumes landfill costs at North and West sites are same as present landfill costs.

(3) Aiken County landfill is operated from county property tax funds. Aiken city residents pay county taxes. Zero disposal cost is presented here since county property taxes will be paid regardless of disposal option selected.

(4) Assume $0.50/ton-mile cost for haul with packer vehicle. See Appendix B.

(5) Cost of transfer facility and vehicle. See Figure 3.1 and Appendix B for cost estimates.

The disposal/resource recovery options for leaf and manure wastes which could have applicability in Aiken are as follows:

- o Landfill disposal
- o Incineration
- o Composting

All three of these alternatives are technically feasible for the disposal of leaf and manure wastes. However, it is likely that incineration will not be as cost-effective as landfilling. The economic feasibility of composting will depend upon whether or not a reliable market can be found for the compost. Composting, as a method of waste volume reduction alone, (i.e. landfilling of the compost) is not an economically viable mode of operation.

Materials Recovery

Currently there are two basic methods in use for separating and gathering reclaimable materials from municipal refuse:

- o Centralized facilities for materials separation
- o Source separation by refuse producers

It is not likely that the relatively small amount of revenue which could be generated from a materials recovery program in Aiken could justify the high capital and operating costs of a centralized "high technology" separation facility. The most practical approach to materials recovery for the City of Aiken would probably be source separation.

Based on a preliminary market survey it was found that markets for recovered paper, glass, aluminum and ferrous metals exist for Aiken.

Solid Waste Collection

The City of Aiken solid waste collection program can be divided into the following three areas:

- o Household refuse (garbage) collection
- o Brush, leaf and miscellaneous bulky refuse (trash) collection
- o Commercial collection

The City of Aiken collects garbage from residents who live within the city limits. The nominal level of service provided is as follows:

- o Twice per week collection
- o Backyard refuse placement
- o Can and/or bag containerization

The performance of the Aiken garbage collection system was compared to other operating systems offering the same nominal level of service and it was found that the Aiken system is comparable to these systems in terms of productivity and cost efficiency. Areas where the operating costs of the Aiken garbage collection system can be reduced were defined as follows:

- o Level of service
- o Routing
- o Personnel productivity

The trash collection system in Aiken picks up yard and garden wastes and miscellaneous bulky rubbish. The system collects residential trash as well as wastes from the many City owned landscaped areas (parks, boulevards, etc.) The equipment used for trash collection in Aiken consists of trucks with detachable trailers. Requiring home owners to containerize or bundle yard and garden wastes would make it practicable to collect this refuse along with household garbage and could reduce the required number of trash crews significantly.

The City of Aiken provides commercial refuse collection service within the city limits. The commercial locations each have one or more containers which are emptied by one of three front loading collection vehicles. The commercial locations are serviced one or more times per week depending upon the amount and type of refuse being produced. A systematic method for determining commercial service charges was developed during the course of this study and is discussed in Chapter 6.

CONCLUSIONS

1. Present Aiken Landfilling Practice

1.1 Portions of the City of Aiken landfill property are presently being used for uncovered surface disposal of yard and garden wastes, white goods and animal wastes. This practice is not consistent with the South Carolina solid waste disposal regulations or acceptable landfilling practice. Uncovered surface disposal of organic wastes can be environmentally unsound and has the potential for affecting the quality of surface water run-off from the Aiken landfill property.

2. Extending the Usable Life of the Aiken Landfill Property

2.1 During the course of this study several methods of extending the usable life of the Aiken City landfill property have been defined. These methods can be categorized as follows:

- o Increased area utilization efficiency resulting from alternative landfilling methods
- o Increased area utilization efficiency resulting from alternative landfill equipment usage
- o Further use of under-utilized portions of the permitted landfill property
- o Re-permitting and use of the non-permitted portion of the landfill property

The estimated technical "potential for success" for each of these options is summarized in Table 1.1.

2.2 The life of the Aiken landfill can be extended by altering the operating methods in the following two areas:

- o Improved cell structure
- o Filling to a higher final grade

These concepts are discussed in detail in Chapter 2.

2.3 Based on general landfill equipment size requirement guidelines it is believed that the crawler loader presently being used at the Aiken landfill is adequate for the quantity of waste being handled.

2.4 Use of a conventional steel-wheeled landfill compactor for refuse and cover spreading and compacting would help extend the usable life of the Aiken landfill. However, it is likely that a conventional compactor would not be versatile enough to perform all of the required landfill functions on a year-round basis. It is believed that a crawler type vehicle is more practical for use at the Aiken landfill under present conditions.

2.5 A scraper could be used to spread and compact cover material at the Aiken landfill. Although scrapers are not particularly effective at compacting refuse, they are relatively heavy and can help when routed over the working area. The purchase of a scraper, however, cannot be economically justified for major excavation alone. The cost of owning and operating a scraper at the Aiken landfill would increase the landfill operating costs significantly. It is unlikely that the use of a scraper would provide enough compaction to increase the life of the Aiken landfill significantly.

2.6 The portions of the permitted area where surface disposal is presently being practiced could be more effectively utilized by either excavation of areas that have not been completely filled and/or by filling on top of the present surface to a higher elevation. If excavation is considered it would be advisable to perform soil borings in the area to identify the locations of buried waste and to characterize the geologic and groundwater conditions.

2.7 There are about 11 acres in the non-permitted portion of the Aiken landfill property where only refuse burning has been done in the past. It is possible that this section of the property could be re-permitted and used for future landfilling. Though it is possible that the area is technically adequate for landfilling, enough information is not presently available to make this conclusion. It will be necessary to obtain more

information about the geologic and groundwater conditions in the area before a landfilling plan can be developed and an application for re-permitting can be made.

3. Future Refuse Disposal Alternatives

3.1 Of the three refuse disposal alternatives which will be available to the City of Aiken in the future (continued sanitary landfilling, incineration, composting), landfilling will be the most practical and economically attractive (note that composting of leaf and manure wastes alone is discussed separately).

3.2 If the Aiken County landfill continues to be supported from county property taxes it is highly probable that it will be more economical for the City of Aiken to haul its municipal refuse to the County landfill than to dispose of it in a City owned and operated landfill. A change to the County landfill could be made in the near future (rather than when the City landfill is exhausted) to reduce disposal costs. The City would then maintain some back-up landfill capacity in case it becomes attractive to reopen the City landfill.

3.3 Preliminary analysis indicates that a refuse transfer system would not have economic advantages over direct hauling with collection vehicles if the City decides to dispose of refuse at the Aiken County landfill (See Table 1.2).

4. Manure and Leaf Waste Disposal

4.1 Landfill disposal is a technically and economically feasible option for the disposal of leaf and manure wastes in Aiken. It is definitely preferable to the uncovered surface disposal technique presently being used.

4.2 Incineration with a pre-dry step is a technically feasible alternative for the disposal of manure and leaf wastes. However, it is doubtful that incineration can compete with landfilling from an economic point of view.

4.3 The leaf and manure wastes produced in Aiken would probably produce a good quality compost with value as a soil conditioner. However, economics dictate that composting of the leaf and manure wastes is not feasible for waste volume reduction alone. It would cost more to compost the wastes and landfill the compost than it would to landfill the non-composted material. To make composting feasible for Aiken it will be necessary to apply the compost to some economically productive use. Examples would be sale of the compost on the open market or use of the compost to reduce City of Aiken soil conditioner costs (for City owned landscaped areas). A survey of the local market for compost has not been made.

5. Materials Recovery and Recycle

5.1 Based on an estimate of the quantity of materials available for recycling in Aiken, it is likely that a centralized high technology materials separation facility cannot be economically justified at present.

5.2 It is possible that a source separation program can be successfully operated in Aiken. However, this would require a high level of continued effort on the part of the organizers and operators.

5.3 Based on a preliminary survey, it is concluded that markets for recovered paper, glass, aluminum and ferrous metals exist for Aiken. Economically successful recovery and sales of these materials will be dependent upon the costs associated with collection, separation and transportation of the materials as well as the existing market conditions (in some cases highly variable).

6. Aiken Garbage Collection System

6.1 The performance of the Aiken garbage collection system is comparable to other systems offering the same nominal level of service from a productivity and cost efficiency point of view.

6.2 It is believed that the operating costs of the Aiken garbage collection system can be reduced significantly by system changes in the following areas:

- o Level of Service
- o Routing
- o Personnel Productivity

6.3 The most significant cost savings would probably be achieved by changing the level of service from backyard to curb side refuse placement. Labor and equipment requirements can possibly be reduced by one-half if curb side placement is used and a task incentive program is instituted.

7. Aiken Trash Collection System

7.1 During on-route observation done over the course of this study it has been noted that a significant amount of the refuse collected by the Aiken trash crews consists of relatively small piles of yard and garden wastes placed at the curb side. These piles are loaded by hand into trailers by the trash collection personnel. This method of trash pick-up is inherently inefficient for the collection of small piles of loose yard wastes.

7.2 It is likely that a significant portion (perhaps all) of the trash collection system work force and equipment could be eliminated if the residents of Aiken were required to containerize or bundle small quantities of loose landscape wastes for collection by garbage crews.

CHAPTER 2
CITY OF AIKEN LANDFILL

Currently the City of Aiken disposes of its residential and commercial refuse in a City-owned and operated sanitary landfill. The landfill is located on the eastern edge of the City and is incorporated within the city limits. The main objective of this chapter is to investigate methods which can be used to increase the usable life of the Aiken city landfill. The following sections will discuss the current landfill utilization, methods and equipment and will present information on extending the usable life of the property.

LANDFILL PROPERTY DESCRIPTION

The Aiken landfill property encompasses about 67 acres. A sketch of the property boundary is shown in Figure 2.1 About 44 acres of the property are presently permitted for waste disposal by the SCDHEC and are currently being used for landfilling. The remaining 23 acres are not presently permitted by the SCDHEC for waste disposal. This portion of the property was at one time permitted and has been used in the past for landfilling and open burning of solid wastes.

Non-Permitted Area Utilization

Figure 2.2 shows the approximate areas of the non-permitted portion where the past burning activities occurred. The areas shown in Figure 2.2 were defined based on:

- Visual observation
- Discussions with the landfill operator
- Auger borings done in the area

During the course of this study, the City of Aiken hired a private contractor to perform investigative soil borings on the non-permitted

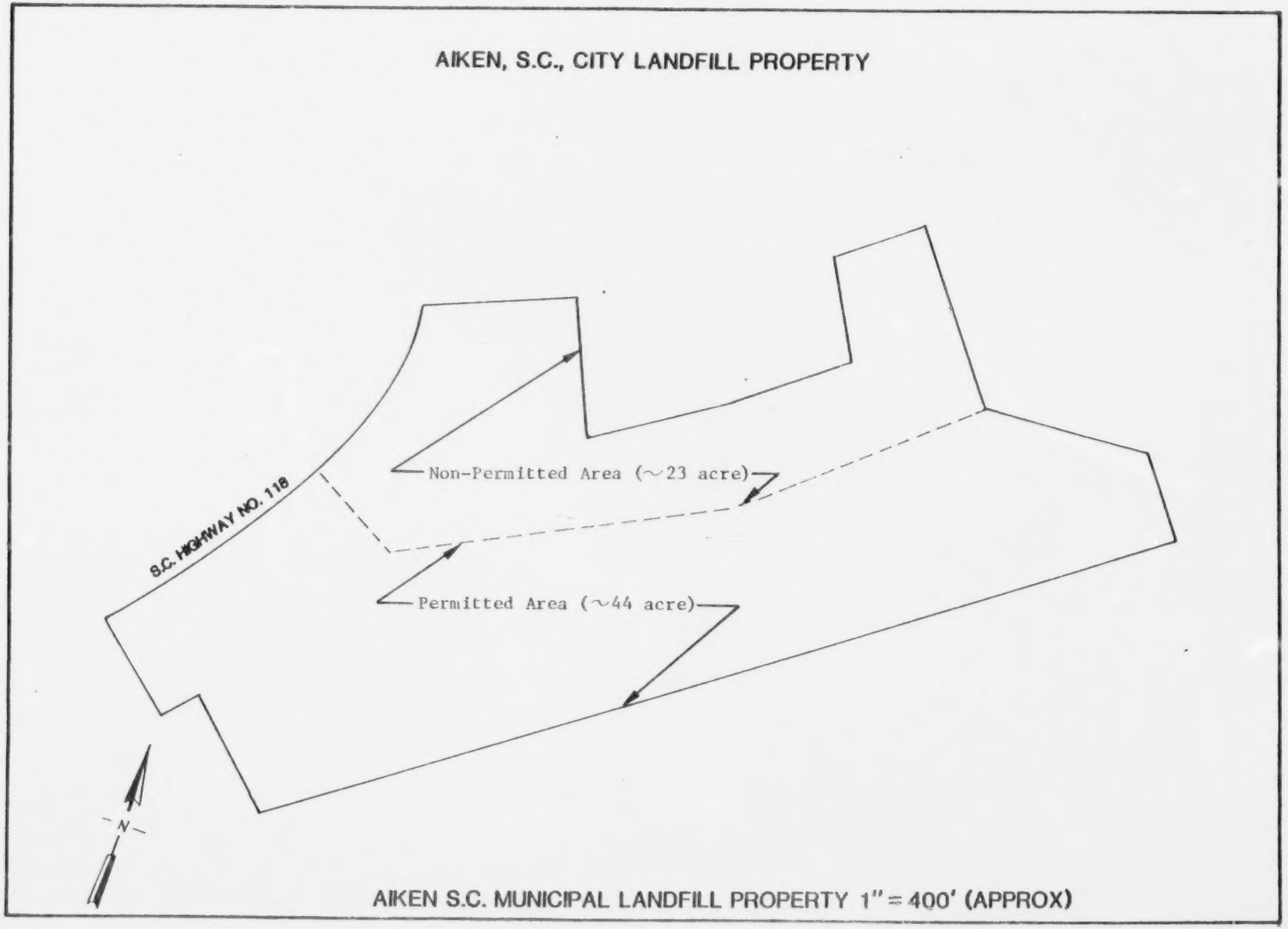
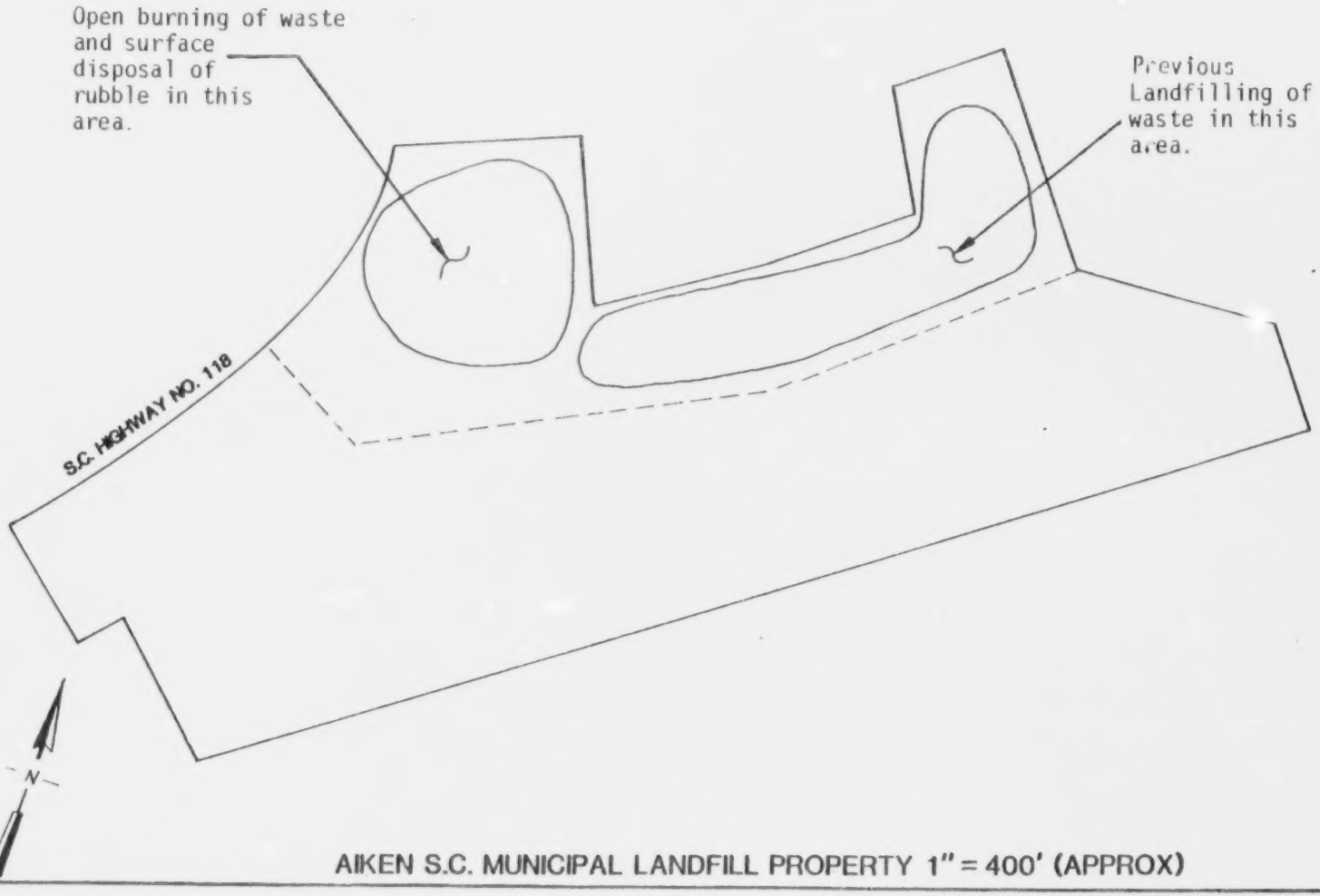

AIKEN, S.C., CITY LANDFILL PROPERTY
Non-Permitted Area (~23 acre)
S.C. HIGHWAY NO. 118
Permitted Area (~44 acre)
N
AIKEN S.C. MUNICIPAL LANDFILL PROPERTY 1" = 400' (APPROX)

FIGURE 2.1

PAST USAGE OF NON-PERMITTED LANDFILL PROPERTY


Open burning of waste and surface disposal of rubble in this area.
Previous Landfilling of waste in this area.
S.C. HIGHWAY NO. 118
N

AIKEN S.C. MUNICIPAL LANDFILL PROPERTY 1" = 400' (APPROX)

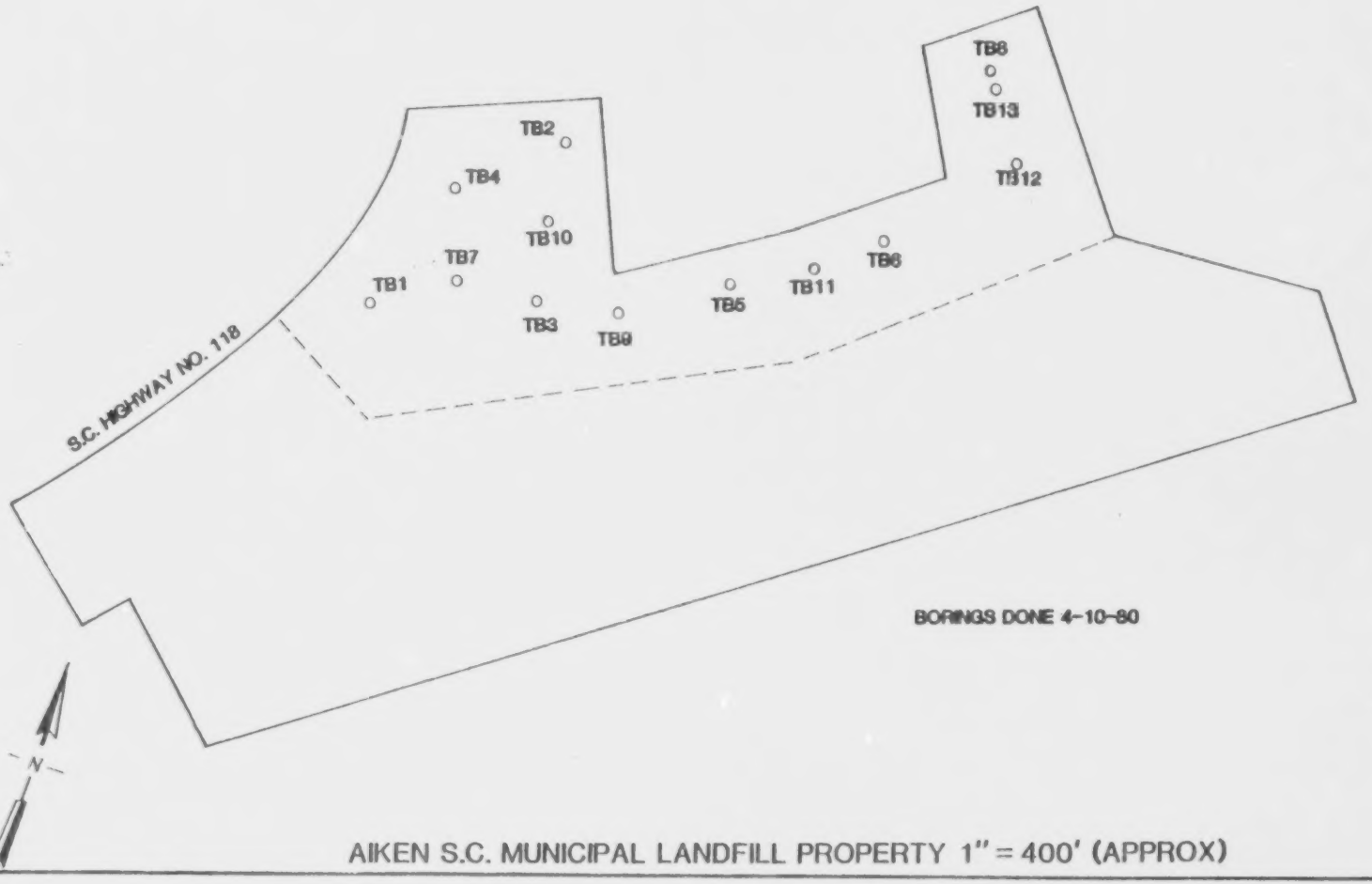
FIGURE 2.2

portion of the landfill property. The borings were done with a truck mounted auger rig and logs were kept by project personnel based on visual observation of the auger cuttings. The boring logs are presented in Appendix A. A total of 13 borings were done on April 10, 1980. The approximate locations of these borings are shown in Figure 2.3

The approximate area which has been used for open burning of waste in the past is shown on Figure 2.2. Portions of the area have been used for surface disposal of limbs and rubble (rock, concrete, etc.) while the remainder has become revegetated. During the soil boring activity, it was observed that this area has little or no top soil. Ash residue was found in the area mixed with sand/clay soil in layers from 1 to 17 ft thick. The greatest quantity of ash was found at TB3 (see Figure 2.3). The ash/soil layers sampled were generally characterized by the dark color of the material and the presence of unburnable debris (glass, wire, etc.). No decayed organic odors from the ash/soil mix were noted.

As shown on Figure 2.2 the central and northeastern portions of the non-permitted property were used for landfilling in the past. The locations tested generally have from 2 to 4 ft of clean soil cover over a layer of refuse ranging from 11 to 17 ft thick. The landfilled refuse was characterized by its dark color (grey to black) and the presence of unburned burnable refuse (paper, cloth, etc.) . In most places, the landfilled refuse was fairly wet and exhibited a decayed organic odor. At several locations, visual observations indicated that the waste was in a saturated condition and possibly below the current water table level. At two locations (TB12 and TB13) the saturated waste had the consistency of a thick milkshake and appeared to be "pumped" to the surface by the auger. It should be noted however that a significant amount of rain had fallen in the Aiken area during the 4 to 6 week period before the borings were done. It is not known if this rain caused the buried waste to be any wetter than normal. Though the extremely wet condition of the buried waste at the Aiken landfill indicates that leaching was occurring it is not known whether or not this leachate was reaching the groundwater table and/or moving laterally beyond the property boundary. Methods

TEST BORING LOCATIONS
AIKEN S.C. CITY LANDFILL



AIKEN S.C. MUNICIPAL LANDFILL PROPERTY 1" = 400' (APPROX)

FIGURE 2-5

which could be used to inhibit waste/water contact and leachate production include improved grading (to enhance drainage and prevent ponding), covering with relatively impermeable material (clay, etc.) and planting of cover vegetation (grass) to increase evapo-transpiration and stabilize cover. It is possible that the city of Aiken could be held responsible if groundwater or surface water contamination were linked to the landfill.

Permitted Area Utilization

The part of the Aiken landfill which is currently permitted for waste disposal by the SCHDHEC consists of about 44 acres in the southern portion of the property (see Figure 2.1). Presently the property is used for several different types of disposal. The approximate disposal areas are shown on Figure 2.4 and described below.

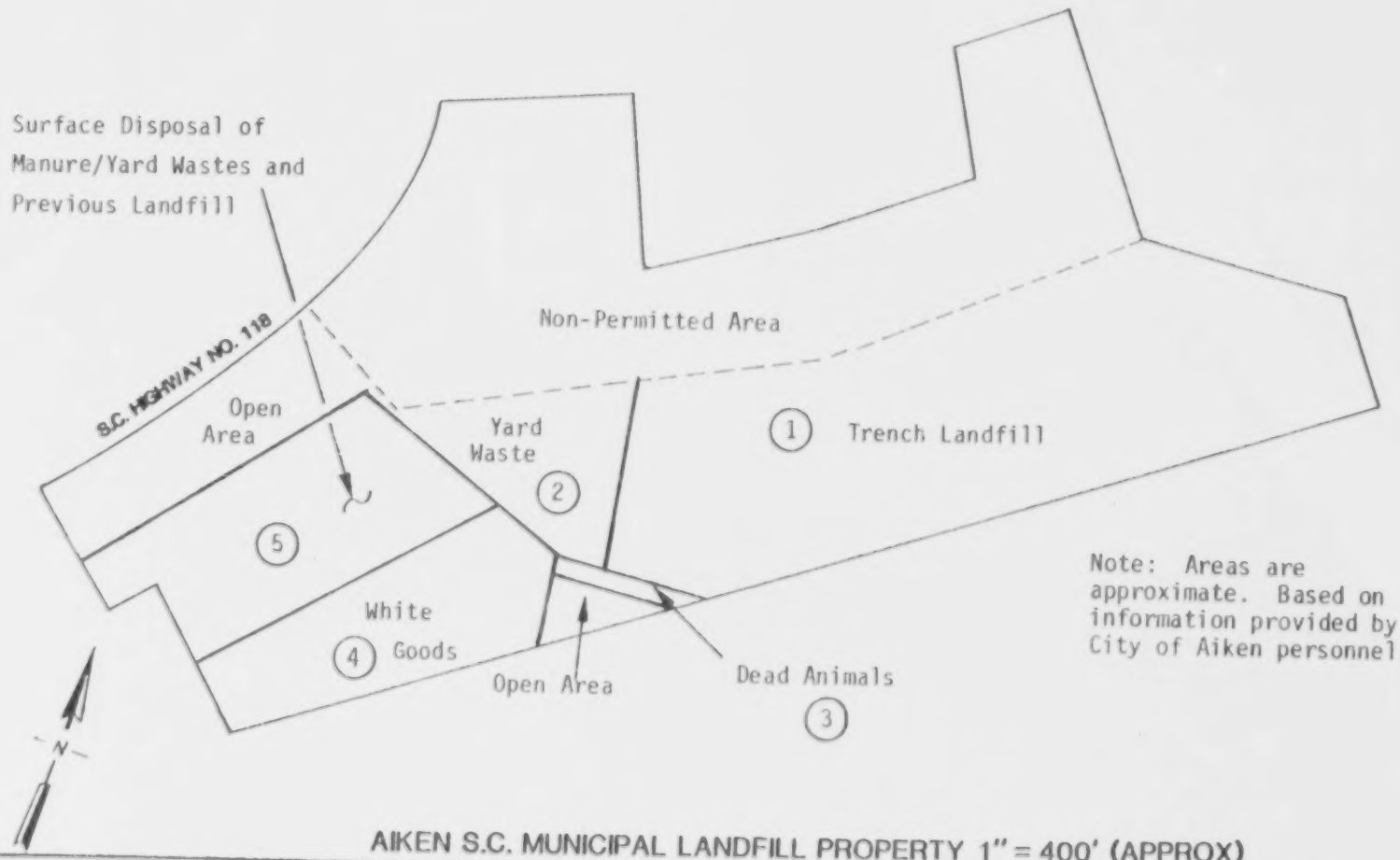
1. Trench landfill of household and commercial refuse ($\sim$21 acres)
2. Surface disposal of landscape waste ($\sim$ 3 acres)
3. Pit disposal of dead animals ($\sim$ 1/2 acres)
4. Surface disposal of hardware and tires ($\sim$ 6 acres)
5. Surface disposal of manure ($\sim$ 7 acres)

Approximately 4 acres of land that borders the highway will not be used for waste disposal. This land will be landscaped for aesthetic purposes in the future.

The open (i.e. uncovered) disposal of landscape waste, manure and hardware classfies at least portions of the Aiken landfill as "open dump" areas as defined in South Carolina Regulation No. R61-70 (Sanitary Landfill Design Construction and Operation). This document is part of the South Carolina Solid Waste Control regulations. The regulation also states that open dumps are prohibited.

As previously stated, approximately 21 acres of the Aiken landfill property is currently used for landfilling of commercial and household refuse. At present about 9 of these 21 acres have been used. The methods and equipment used for landfilling are discussed in the following sections of this chapter.

PERMITTED AIKEN LANDFILL PROPERTY
AREA UTILIZATION



AIKEN S.C. MUNICIPAL LANDFILL PROPERTY 1" = 400' (APPROX)

FIGURE 2.4

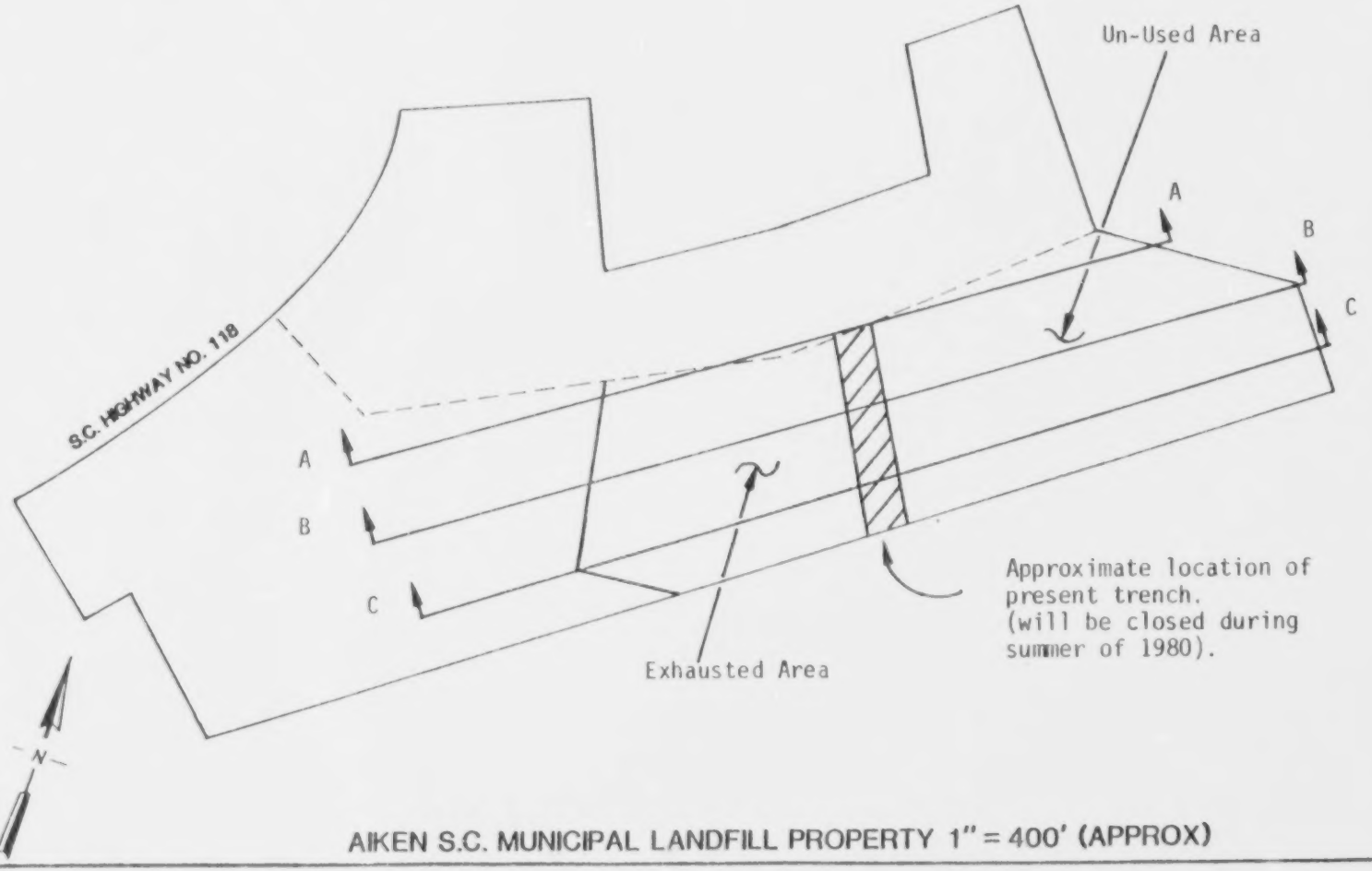
LANDFILLING METHOD

In 1973 a controlled landfilling method was begun at the Aiken City landfill. The present trench has been utilized for about 11 months and will be closed shortly. The approximate location of the present trench is shown on Figure 2.5. The area to the southwest of the trench has been exhausted during past landfillling activities and the area to the northeast of the trench is presently virgin property. Figure 2.6 shows ground surface elevation profiles of the area being used for landfilling and the approximate location of the present trench (note that sections are defined on Figure 2.5). The terrain of the land can be described as gently rolling with slopes of about 0.5 to 12%.

The method currently being used for landfilling at the Aiken City landfill is conceptually diagrammed in Figure 2.7. The method is a combination of the standard trench and ramp landfill methods. The first step is to dig the trench in virgin soil (i.e. not previously landfilled). The excavated soil is stockpiled on the working side of the trench. The present trench was about 20-30 ft deep and 100 ft wide at the bottom with the working face sloped at about 4:1 when constructed. The trench is filled by forming ramp-type refuse cells on the working face of the trench (see sketch Number 2 on Figure 2.7). The collection vehicles dump the refuse at the top of the working face and a crawler-type loader spreads and compacts the refuse in about 2 to 3 ft. layers. When the loader is at the bottom of the trench, it cuts a load of soil from the opposite face of the trench (sloped at about 1:1) and spreads this material for cover as it climbs the working face. Once on top the loader picks up a load of soil from the stockpile of excavated material and spreads it as it proceeds down the working face. In this manner the refuse is compacted and daily cover is applied. It has been estimated that an average of about 1 ft of daily cover material is provided. Since material is placed into the trench at a greater rate than it is cut away from the non-working face of the trench, the trench continually becomes narrower as landfilling proceeds.

SURFACE ELEVATION PROFILE SECTIONS

Note: See figure 2.6 for section profiles.



AIKEN S.C. MUNICIPAL LANDFILL PROPERTY 1" = 400' (APPROX)

FIGURE 2.5

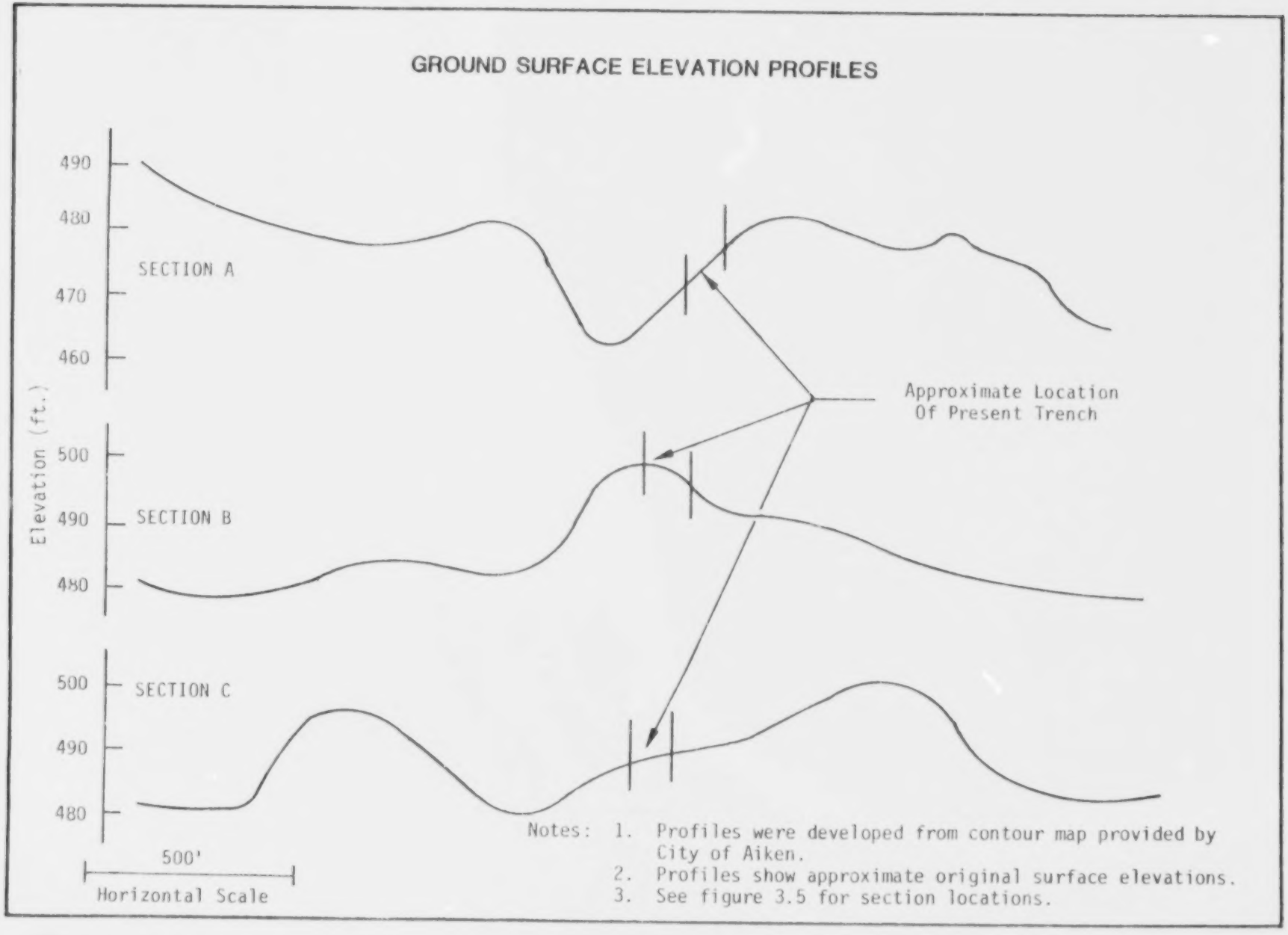
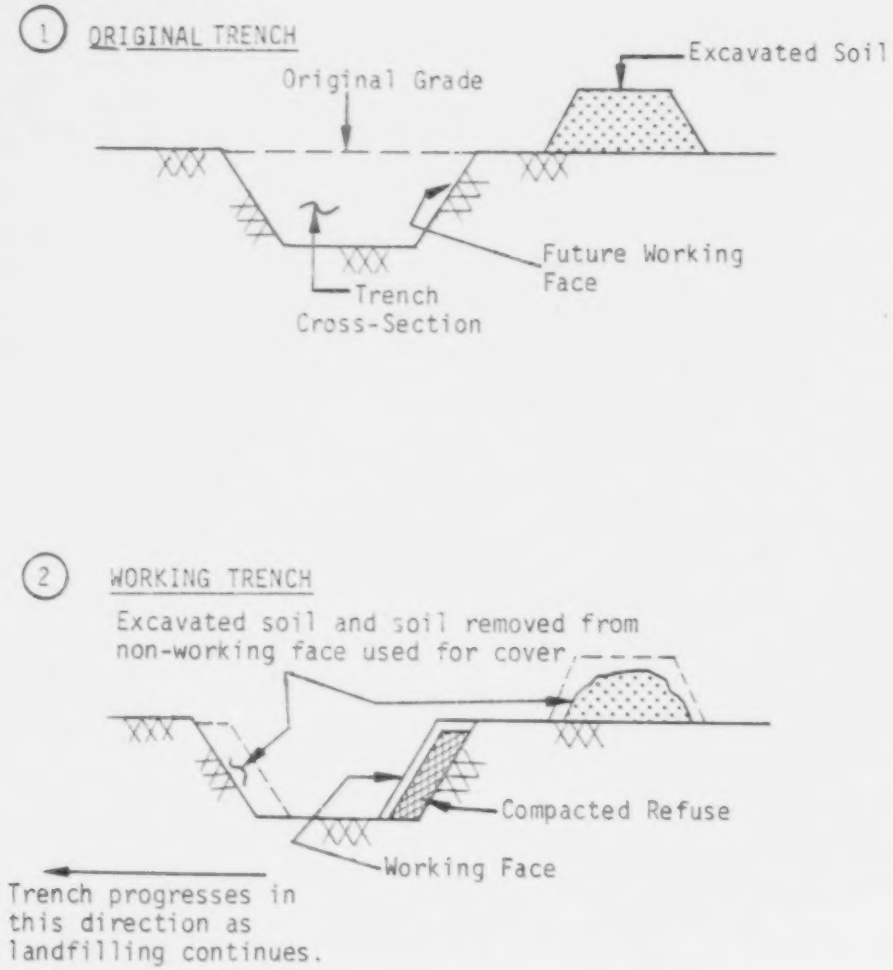

GROUND SURFACE ELEVATION PROFILES
Elevation (ft.)
490
480
470
460
SECTION A
500
490
480
SECTION B
500
490
480
SECTION C
Approximate Location
Of Present Trench
500'
Horizontal Scale
Notes: 1. Profiles were developed from contour map provided by City of Aiken.
2. Profiles show approximate original surface elevations.
3. See figure 3.5 for section locations.

FIGURE 2.9

CONCEPTUAL REPRESENTATION OF LANDFILLING METHOD USED AT AIKEN CITY LANDFILL



The City of Aiken personnel realized that if landfilling was done using a series of parallel trenches that a considerable amount of landfill volume would be wasted between each trench. This situation is pictured in Figure 2.8. If it is assumed that a 10 ft gap would be used between trenches and that the trench is widened by 10 ft during filling (a realistic estimation based on the experience with the present trench) the resulting volume wastage would be about 25%. To prevent this the City of Aiken personnel plan to widen the trench with heavy duty earth moving equipment before it becomes full. This procedure causes the trench to continually move laterally. When the landfill is completed it will consist of one continuous layer of refuse and cover material rather than a series of buried parallel trenches. This represents a sound method of operation.

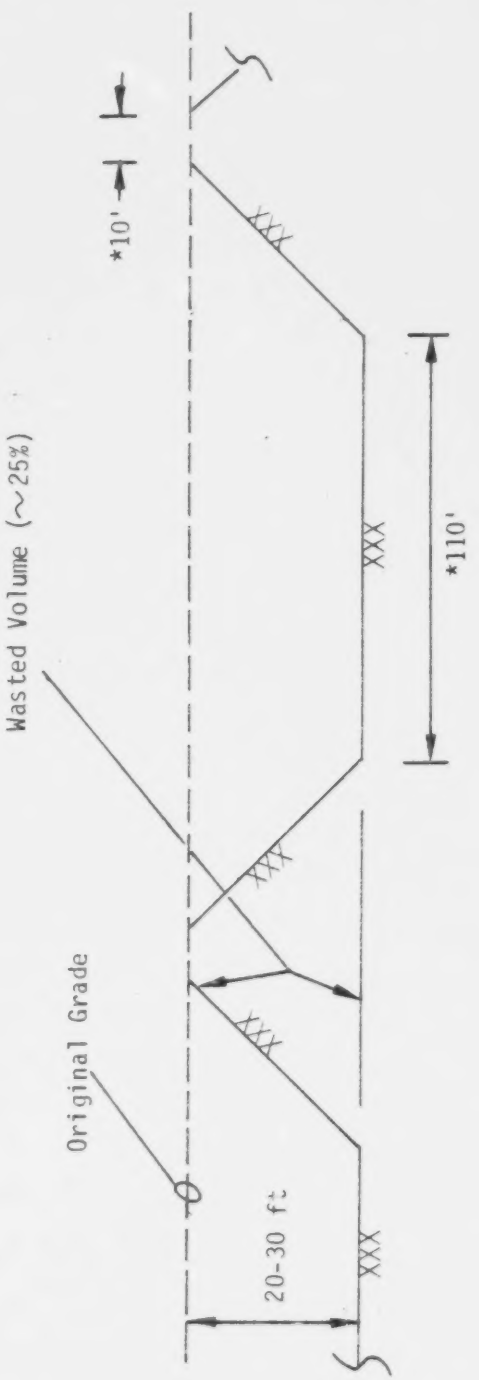
At the present time the Aiken landfill trench is nearly closed. An excavation is planned for the summer of 1980 to widen the trench. To prevent the trench from closing and to allow enough room on the bottom of the trench for equipment maneuverability, it has been necessary to increase the working face slope. Currently the working face is sloped at about 1.5:1 or 2:1. The landfill operators intend to redevelop the 4:1 working face after the trench has been widened.

LANDFILL EQUIPMENT

At present one piece of heavy equipment is used on a regular basis for working the Aiken landfill. The unit is a city-owned crawler-type loader (Caterpillar Traxcavator, Model No. 977L) with landfill accessories. The unit weighs about 48,000 lb and has about 190 flywheel HP. The loader is equipped with engine and radiator screens, a reversible fan, and roll-bar protection. City of Aiken personnel believe that the loader is past its useful life and should be replaced in the near future due to increasing maintenance problems.

When the present trench was constructed at the Aiken landfill a private contractor was hired to do the excavation. A scraper was used to dig the trench. The present plan is to hire an independent contractor to do the excavation required to widen the trench.

CROSS SECTION OF LANDFILL TRENCHS



*Dimensions Assumed

EXTENDING LANDFILL PROPERTY USABILITY

During the course of this study several methods for extending the usable life of the Aiken City landfill have been defined. These methods can be categorized as follows:

- o Increased area utilization efficiency resulting from alternative landfilling method
- o Increased area utilization efficiency resulting from alternative landfill equipment usage
- o Further use of under-utilized portions of the permitted landfill property
- o Re-permitting and use of the non-permitted portion of the landfill property

These approaches are discussed individually in the following subsections.

Alternative Landfilling Method

Landfilling method generally refers to several aspects of landfilling procedure. Three basic aspects are:

- o Placement of the cell with respect to the natural grade of the land.
- o Placement of the cell with respect to adjacent cells.
- o Physical shape and structure of the cell.

Here, and where henceforth mentioned, the word "cell" shall be defined as:

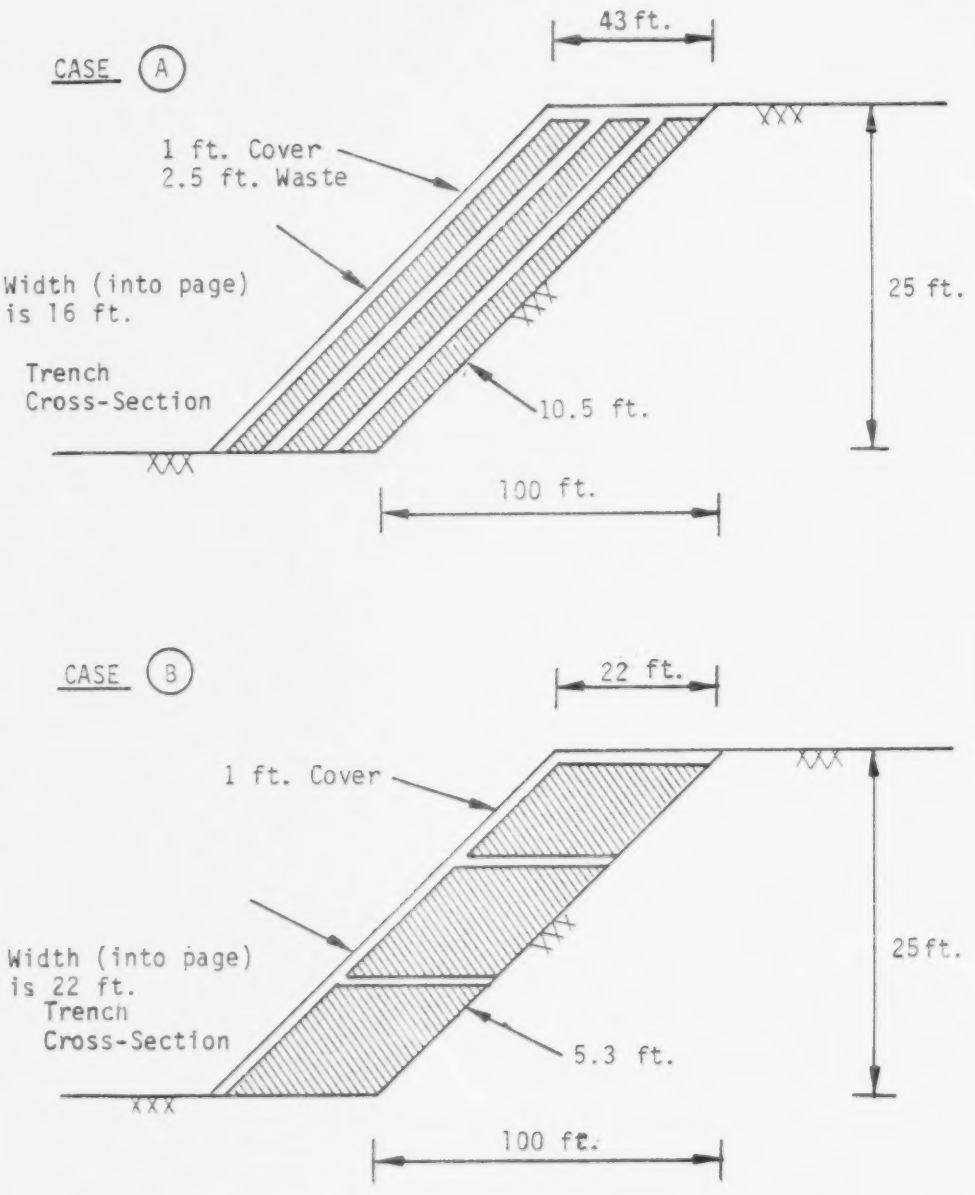
> A single continuous body of landfilled refuse which is totally separated from all other bodies of landfilled refuse by cover material and/or undisturbed soil.

The basic refuse cell structure can have a significant impact upon landfill volume utilization efficiency (and thus area utilization efficiency). An increase in volume utilization efficiency can be achieved if the volume of intermediate (daily) cover required per unit volume of in-place refuse can be reduced.

An illustrative example using a 25-ft deep trench is shown in Figure 2.9. The two sketches show idealized cross sections of the working face of the trench. In both cases equal amounts of waste

FIGURE 2.9

EXAMPLE ILLUSTRATING HOW CELL STRUCTURE CAN AFFECT VOLUME UTILIZATION



have been disposed and one foot of daily cover has been provided. However, the cells in Case B have been structured differently than those in Case A (note that Case A is an idealized version of the cell structure used at the Aiken landfill with fill to grade). The cells in Case B are more compact and require less cover per unit volume of refuse. In Case B about 13,000 tons of compacted waste have been filled per acre of landfill area while only about 11,000 ton/acre have been disposed of in Case A. This represents an increase in landfill volume utilization efficiency of about 20%.

The method which is presently employed at the Aiken City landfill results in a fill which extends from 20 to 30 ft below natural grade with final cover placed at 2 to 10 ft above natural grade. One concept that could be used to increase area utilization efficiency (i.e. increase the volume of waste landfilled per acre) is to increase the total thickness of the waste layer. This could be applied to the present method by increasing the depth of the trench and/or increasing the final elevation of the fill. City of Aiken personnel have stated that it is not possible to increase the depth of the trench and still maintain adequate drainage of the trench.

The usable life of the Aiken landfill could probably be extended by increasing the final elevation of the fill. City of Aiken personnel have expressed a desire to make the landfill aesthetically attractive and compatable with the surrounding land area after final closure. This is a commendable attitude. It should be realized, however, that these goals can be achieved even if the final ground surface is considerably higher than the surrounding ground surface providing proper consideration has been given to:

- o major surface water drainage paths
- o erosion protection
- o landfill structural stability

Implementation of this concept would require the development of a detailed plan for the final cover topography considering each of these factors. However, it is reasonable to expect that with proper

planning the average final elevation of the fill could be 15 ft above natural grade without having adverse effects on the surrounding environment.

The volume and area utilization efficiency of a landfill can also be increased if the quantity of soil required to provide adequate daily cover can be reduced. Usually landfills can be operated such that 6 to 12 inches of daily cover is provided and about 20% of the landfill's volume is occupied by cover soil (4 parts refuse to 1 part cover). Normally about 6 inches is required to prevent blowing litter and keep vermin from entering the refuse. However, because it is very difficult to apply a uniform 6-inch soil cover to compacted refuse, 12 inches is usually a more realistic objective. There are certain steps which can be taken to make it easier to apply a uniform cover layer which is not excessively thick. One procedure which can help to apply uniform cover and provide more effective compaction is to form the cell and compact the refuse before placing the cover soil. It is difficult to apply a uniform layer of cover to loose refuse. It is also helpful to maintain moderate working slopes.

Alternative Equipment Usage

The loader which is used to work the Aiken landfill was described in a previous section of this chapter. It was also mentioned that the City of Aiken personnel believe that the loader requires excessive maintenance and needs to be replaced. It is assumed that this is true and the unit will be replaced with a similar model or alternative type which is in good working condition in the near future.

Table 2.1 shows landfill equipment requirement guidelines which were published by the U.S. EPA in 1972. These guidelines are supported, in general, by information published by the Department of Health, Education and Welfare (Publication No. 1792). It is estimated that approximately 224 tons/week of combined commercial industrial and household refuse is disposed of in Aiken. If this quantity of material is landfilled in five 8-hr working days this corresponds to about 45 tons/8-hr period. According to the guidelines in Table 2.1 this quantity of waste would require a crawler loader weighing 20,000 lb with 100 flywheel HP. This is about 1/2 the size and power of the present Aiken loader. The guidelines in Table 2.1 are based on

TABLE 2.1

LANDFILL EQUIPMENT REQUIREMENT GUIDELINES

Solid Waste Handled (ton/8 hr)	Crawler Loader		Crawler Dozer		Rubber-tired Loader	
	flywheel horsepower	weight (lb x 1000)	flywheel horsepower	weight (lb x 1000)	flywheel horsepower	weight (lb x 1000)
0-20	< 70	< 20	< 80	< 15	< 100	< 20
20-50	70-100	20-25	80-110	15-20	100-120	20-22.5
50-130	100-130	25-32.5	110-130	20-25	120-150	22.5-27.5
130-250	150-190	32.5-45	150-190	30-35	150-190	27.5-35

Notes:
1. Data taken from "Sanitary Landfill Design and Operation" U.S. EPA Report Number SW-65 ts.
2. Requirements are based on ability of one machine to spread, compact and cover within 300 ft of working face.
3. Performance is based on a survey of equipment manufacturers' literature.

one piece of equipment for refuse spreading, covering and compaction. It should be noted, however, that the performance used to develop the guidelines was taken, for the most part, from vendor literature and can only be used for rough estimates for specific applications. However, it is believed that the size of the loader being used in Aiken is appropriate for the waste stream being landfilled.

Special compactors have been developed for landfill work. These units are constructed similarly to road compactors. Landfill compactors are usually equipped with trash blades and have studded steel wheels to increase compaction effort. A study discussed in a 1972 U.S. EPA report (previously mentioned and referenced on Table 2.1) compared the compaction efficiencies of a 47,000 lb landfill compactor and a 62,000 lb crawler-dozer. The results showed that the compactor achieved an in-place refuse density which was 13% greater than the heavier crawler-dozer. Another advantage that landfill compactors have over crawler type units is that they can move much faster. When spreading and compacting refuse on a level surface compactors can move as fast as 20 to 25 mph while crawlers can only move about 8 mph under the same conditions. One disadvantage that conventional landfill compactors have is that they are not able to develop good traction. This makes them poor for use on steep slopes and for heavy excavation purposes. The lack of traction also makes steel wheeled compactors difficult to operate in wet or soft soils. Use of a landfill compactor could produce higher in-place refuse density and thus increase the usable life of the Aiken landfill. However, based on all considerations it is doubtful that a conventional steel wheel landfill compactor alone would be versatile enough to perform all the necessary equipment functions at the Aiken landfill. It is also worth noting that steel wheel compactors generally do not have a good re-sale value due to their limited usefulness.

The trench at the Aiken City landfill was excavated with a scraper by a private contractor. Scrapers are used at some landfills for excavation and spreading of cover material. It has been found that scrapers are particularly useful when cover material must be hauled relatively long distances. It is believed that if the working face

at the Aiken landfill is maintained at a moderate slope that the use of a scraper for excavating and spreading cover material is technically feasible. It must be realized, however, that purchasing and operating a scraper will increase the total landfill operating costs considerably. It was estimated that the total current cost for operating the Aiken landfill is about $9.5/ton of disposed refuse (including annual major excavation by a private contractor; see Appendix B for cost estimates). If an 11-cu yd scraper were purchased and operated at the Aiken landfill it is estimated that the total landfill cost would be increased to about $11.2/ton; an 18% increase. This estimate allows all heavy excavation to be done with the purchased scraper rather than by an outside contractor.

Based on the available information the following conclusions are offered concerning equipment requirements at the Aiken city landfill.

- The crawler type loader presently being used at the Aiken landfill is probably adequately sized for the quantity of refuse being filled.
- Conventional landfill compactors usually are quicker landthan crawler vehicles and make more efficient use of landfill area. However, crawlers are more versatile and can perform more effectively under adverse soil and weather conditions. It is likely that a crawler type vehicle is more practical than a landfill compactor for use at the Aiken landfill if only one piece of refuse handling equipment is to be used. It is doubtful that the use of more than one piece of refuse handling equipment at the Aiken landfill could be economically justified at present.
- Purchase and operation of a scraper cannot be economically justified for major excavation alone at the Aiken landfill. It has been estimated that use of a 11-cu yd scraper at the Aiken landfill would increase the total landfill costs by about 18% (allowing for outside contract of major excavation if no scraper is purchased).

Under-utilized Portions of Permitted Area

Figure 2.4 shows how various portions of the permitted part of the Aiken landfill property have been used for waste disposal. About 16 acres of the land are currently being used for surface disposal of yard waste, white goods and manure. The combination of these areas will be referred to as the surface disposal area. It is not known at present exactly how much waste has been buried in the surface disposal area in the past though the landfill operators believe that a significant portion of the area has been fully utilized.

If there are portions of the surface disposal area where significant quantities of waste have not been buried, it is possible that the surface wastes could be cleared and the land used for landfilling. Since surface disposal is wasteful it is probable that the surface wastes could be landfilled here as well as an amount of additional waste. This would have two positive effects: providing additional landfill capacity and cleaning up the landfill. As previously stated, the uncovered surface disposal of refuse is not permitted by the South Carolina solid waste disposal regulations. Before excavation of the surface disposal area for landfilling, borings should be taken in the area to identify buried waste locations and groundwater table elevations. If significant quantities of buried unburned waste were excavated there could be health and odor risks.

Though it may not be practical to excavate for further landfilling in the surface disposal area it would probably be possible to do additional landfilling in this area by increasing the fill elevation. If this option is considered it will be necessary to develop a filling plan taking into consideration drainage and erosion control.

Under-utilized Portions of Non-Permitted Area

Figure 2.2 shows how the non-permitted portion of the Aiken landfill property has been used in the past. The southwest portion of the area was used for burning and surface disposal of rubble while the central and northeast areas have been used for landfilling. It would probably be unwise to do any excavation in the landfilled area due to potential health and odor problems. The soil borings in

this area indicated that the waste is quite wet and biologically active.

It may be possible, however, to make further use of the burning area. This would make approximately 11 more acres of the property available for landfilling. During the soil boring activity it was noted that the buried waste layer in the area consisted of ash mixed with soil and unburned debris (glass, wire, cans, etc.). No decayed organic or other offensive odors were detected.

Before landfilling in the burning area the following steps should be taken:

- The requirements for re-permitting of the area by the SCDHEC should be investigated. The landfill plan should be compatible with these requirements.
- A more thorough investigation of the subsurface hydraulic and geologic conditions in the area should be made using soil borings (or other means).
- The area should be re-permitted.
- The area should be cleared of surface wastes and plans should be made for proper disposal of these wastes. A detailed plan should be developed for landfilling in the area. This plan should include among other things, filling methodology, final grade elevation and post-closure usage.

The SCDHEC Environmental Quality Manager for the Lower Savannah District was contacted and asked about the possibility of re-permitting of the burning area. He unofficially stated that this action was possible if adequate subsurface information were obtained and state regulations were followed in permitting, landfilling and closure of the area.

SUMMARY OF LANDFILL LIFE EXTENDING ALTERNATIVES

A variety of concepts have been defined which have potential for increasing the usable life of the Aiken City landfill property. These concepts were discussed in detail in the previous section of this

chapter. Conclusions were developed concerning the technical feasibility of the various concepts. The options for extending the usable life of the landfill were grouped into four general categories. Table 2.2 summarizes the options which have been discussed and indicates the estimated potential for success of each. An estimate was made of the usable life of the Aiken landfill if the viable life extension concepts were applied. It was estimated that the remaining life of the landfill property could be increased to about 15 or 16 years (see Appendix D). This represents an increased life of 7 to 9 years over continued landfilling using the present method and area.

TIRE DISPOSAL

City of Aiken personnel have specifically requested information on the disposal of tires. Currently surface disposal is used for tires and the City of Aiken wishes to discontinue this practice. This topic will be addressed here.

Resource Recovery

A limited percentage of tire casings can be used for retreading. Recovering the remainder for energy or material value is very difficult. Until an effective method for recovery has been developed, a community is limited to disposal.

Reef Construction Project

A feasibility study by the South Carolina Marine and Wildlife Resources Department for state-wide tire disposal is in progress. The concept of disposal is to bind the tires together and deposit them off the shore of South Carolina to create an artificial reef. It is believed that small aquatic organisms (coral, etc.) affix themselves and cover the tires with calcareous material. A reef like this could become a site for feeding by larger aquatic life forms. The concept not only provides disposal of tires but also creates a site for an aquatic community and, possibly, a good fishing location.

It is not known what the City of Aiken's costs would be for participating in the program. There could be costs associated with

TABLE 2.2

SUMMARY OF CONCEPTS FOR EXTENDING USABLE
LIFE OF AIKEN LANDFILL PROPERTY

General Concept	Potential for Success[1]		Further Study Required to Establish Technical Viability
	Good	Poor	
Improved landfill methods	X		
Alternate equipment usage		X	
Further use of under-utilized portions of landfill property:[2]			
Presently permitted area	X		X
Presently non-permitted area	X		X

(1) Refers to technical potential for extending present landfill service life. Major economic benefits would be from the deferment of development costs for a new landfill.

(2) Refers to portions of property which are not presently being landfilled and are not in the area where future landfilling is currently planned.

transport of the tires to a central collection point and perhaps a disposal fee.

Landfill Disposal

Tires can be quite difficult to directly landfill. If placed in the landfill cell along with other refuse they will eventually work themselves to the surface as compactive effort is applied by the landfill equipment. There are, however, several methods which can be used to successfully landfill tires.

A variety of tire shredders are available commercially. These 'achines break tires into small pieces of rubber. Once tires have been shredded they can easily be landfilled along with other refuse. The purchase and operation of tire shredders can be costly. Normally their use is feasible only in locations where a relatively large quantity of tires must be disposed.

There is another method for landfilling tires which is simple and relatively inexpensive. The idea is to place the tires into a pit and cover them with soil. A tire pit can be located apart from the refuse landfill area or can be placed in the buried refuse just below final cover. The key is to cover the tires in a location where they will not be disturbed by the landfill equipment during compaction. The pit method is simple and it has been used successfully at a number of operating landfills. The pit method appears to be extremely practical for application at the Aiken landfill.

CHAPTER 3
REFUSE DISPOSAL ALTERNATIVES FOR THE CITY OF AIKEN

The City of Aiken disposes of commercial, residential and landscape refuse at a landfill which is located within the city limits. It is estimated that the landfill area will be exhausted in 7 to 8 years using the present landfilling method (see Appendix D). The objective of this chapter is to present and discuss refuse disposal options which are available to the City of Aiken both in the near future and when the present landfill has been fully utilized.

DISPOSAL TECHNIQUES

At present there are three basic methods commonly used for municipal refuse disposal:

- o Sanitary landfilling
- o Incineration
- o Composting

Currently the most commonly used alternative is sanitary landfilling.

Incineration has been used since the late 1800's for the disposal of municipal refuse and is especially attractive in situations where landfilling space is limited. However, incineration is not an ultimate disposal technique; landfill space is still required for ash and unburnable residue disposal. Incineration facilities require relatively large initial capital expenditure and incur rather high operation and maintenance costs. Normally, in a location where

adequate landfill space is available, incineration is not the most economically attractive refuse disposal option.

Composting has been successfully used as a method for municipal waste disposal and resource recovery (note that composting of manure and landscape wastes alone is discussed separately in Chapter 4). The practice of composting has two basic positive effects:

- o A net reduction in refuse mass and volume occurs due to biological degradation.
- o The finished compost has a value as a soil conditioner.

Composting of combined municipal solid waste has been more successful in Europe and Asia than it has in the United States due to the following facts:

- o European and Asian refuse normally has a much lower cellulose content due to a lower percentage of paper and thus produces a compost with higher nutrient value.
- o The demand for compost as a soil conditioner has been higher in Europe and Asia than it has been in the United States.

Composting results in a net reduction in solid waste volume and can be used strictly as a means for reducing the quantity of solid waste which must be landfilled. However, the landfill cost savings usually do not offset the cost of the composting process. In general it can be said that under current conditions a market for the finished compost must be available to make composting an economically attractive method for municipal solid waste disposal. A more detailed discussion of composting processes is presented in Chapter 4.

At present landfilling is the most economically attractive method of refuse disposal in most situations where landfill space is available. It is likely that continued landfilling will be the most practical and inexpensive refuse disposal option for the City of Aiken in the coming years.

When the present Aiken landfill is exhausted the City of Aiken will have two landfill alternatives:

- o To establish a new landfill site
- o To dispose of municipal refuse in a landfill which is operated by some other entity

The following sections of this chapter discuss the feasibility and economics of these two options. The concept and economics of large scale solid waste baling and transfer will also be presented since these techniques could have an impact upon future solid waste management decisions.

ESTABLISHMENT OF A NEW CITY LANDFILL

One potential solution to the future problem of solid waste disposal for the City of Aiken is to establish a new City-owned and operated landfill. A new City landfill should not be opened before the existing landfill has been fully utilized because of the large capital expenditure involved. However, in the interest of future planning, City of Aiken personnel have located several land parcels which are available for purchase or lease. Brief site visits were made to these land parcels as a part of this study.

One land parcel which is available for purchase is located approximately 0.7 miles north of the City limits; about 0.9 miles east of State Route No. 19. This parcel shall be referred to as the North Site. The land parcel is larger than would be required and several alternate portions could be purchased and used for landfill siting. Most of the land is lightly wooded but some sections have been used in the past for crops and would require little or no clearing. The terrain of the North Site can be described as rolling to hilly. The surface soils observed appeared to be primarily composed of sand. Information provided by City of Aiken personnel indicates that the surface water run-off from this area enters Shaw's Creek upstream from the City's drinking water supply source. This fact could render the North site technically unacceptable for landfill siting.

Another possible site for a new Aiken landfill is located approximately 0.5 miles west of the University of South Carolina Aiken campus

on State Route No. 80 (south side of road). This land parcel will be referred to as the West Site. At present the owner of the West Site is not willing to sell the property but will consider leasing it to the City of Aiken. The land appeared to be moderately to heavily wooded with flat to rolling terrain. Based on information provided by City of Aiken personnel, drainage of a landfill located at the West Site would require that a culvert be placed under State Route No. 80. As with the North Site, the West Site appeared to have surface soils which are primarily composed of sand. Sandy soils are generally not desirable for landfill siting because of high permeability.

The information necessary to technically evaluate the usability of the North and West Sites for landfilling is not presently available. Before siting a landfill on either one of these land parcels (or any other for that matter) the following information must be obtained:

- o Site topography
- o Site surface water drainage characteristics
- o Site groundwater elevations
- o Site groundwater movement characteristics
- o Site subsurface soil characteristics

USE OF A LANDFILL OPERATED BY OTHERS

It is possible that the City of Aiken could dispose of its municipal refuse in a landfill which is not operated by the City when the present landfill property has been exhausted or sooner if advantages can be identified. The largest landfill in the area is operated by Aiken County. The County landfill is located approximately 12 road miles from the center of the City of Aiken. The landfill is located in an abandoned kaolin pit southwest of the City, between Aiken and the City of North Augusta.

During the course of this study the Aiken County Administrator was contacted. He stated that the City of Aiken would be allowed to dispose of its municipal refuse at the County landfill. At present there would be no per ton or tipping charge for this service. Currently most of the County's refuse (other than that from the City of Aiken) is disposed of at the County landfill; including the solid

waste from the City of North Augusta (population approximately 14,000). The County Administrator estimates that the landfill has a remaining usable life of 6 to 10 years. He stated that other pits are available for future County landfill siting.

The financing of the County landfill operation is a major consideration. The County Administrator stated that the County landfill is operated using money from county property taxes. City of Aiken residents pay county property taxes as well as city property taxes. In brief, the property owners of the City of Aiken are paying a portion of the operating costs for the County landfill, a landfill which they are not presently using on a regular basis.

ECONOMICS OF SOLID WASTE MANAGEMENT OPTIONS

As previously stated, the City of Aiken will have two options for landfill disposal of its municipal solid waste in the future. One possibility is to purchase or lease a land parcel and establish a new City landfill. The other option is to utilize the service at the County landfill.

Both of these options have costs associated with them. If a new City landfill is constructed, significant initial capital costs and annual operating and maintenance (O&M) costs will be incurred. However, it is possible that a new City landfill could be located near Aiken and the cost of hauling refuse to the landfill with packer vehicles could be minimized. At present the County landfill is operated using money from county property taxes (of which the City of Aiken residents pay a share) so no additional capital or O&M costs would have to be paid by the City of Aiken. However the County landfill is located about 12 road miles from downtown Aiken and the cost associated with hauling waste there could be significant.

Large Scale Solid Waste Baling

Solid waste baling facilities are used for compacting large amounts of relatively loose refuse into denser, more easily handled bales. Typically, conventional packer vehicles will compact refuse to a density of about 500 lb/cu yd. If dumped from the packer vehicle at the landfill the waste will assume an in-place density of about

800 lb/cu yd with the compaction provided by overburden pressure and landfill equipment. Over long periods of time, through the action of continued pressure and biological decomposition, the refuse will attain an in-place density of approximately 1000 lb/cu yd. Depending on the type of baler used, bales can be formed that have densities of 1000 to 2000 lb/cu yd.

Some positive effects that occur as a result of using baling operations are as follows:

- o Since refuse volume is reduced when baled, the life of the landfill is extended.
- o Bales are easier to handle than loose refuse.
- o Bales can be less expensive to transport than loose refuse if rail hauling is used.
- o Balers can be used to bale reclaimed materials separately for sale.

Some disadvantages of baling are listed below:

- o Baling facilities require substantial initial capital investment and operating costs.
- o Due to road weight limitations, bales cannot be transported at a significantly lower cost than loose refuse (packer vehicle density) when trucks are used for hauling.
- o Currently there are some gaps in the knowledge of gas production and leachate formation in balefills.

In the case of Aiken, the distance to any of the possible landfills and existing facilities are not such that baling can be used to reduce refuse hauling costs (rail haul is not feasible). Also it is very doubtful that a large baler could be justified solely for the purpose of baling reclaimed materials. The only evident advantage that baling would have for Aiken is a reduction in landfill capacity utilization rate.

The economic aspects of solid waste baling were investigated for the City of Murray, Kentucky during a 1979 Technical Assistance study. Murray is a town of about 15,000 persons; approximately the same size as Aiken. It is likely that Murray and Aiken have similar solid

waste production rates. A cost comparison of baling facility/balefill versus conventional landfilling was done. It was determined that, although a balefill would be less expensive to operate than a conventional landfill, the added cost of the baling facility makes conventional landfilling more economically attractive. It is probable that a similar analysis for Aiken would yield the same general results.

It is concluded that large scale baling of the refuse collected in Aiken is not at this time an economically viable alternative.

Solid Waste Transfer

Solid waste transfer systems (combination of transfer facility and transfer vehicle) are often used to reduce the costs of hauling refuse. Refuse collection vehicles transport the solid waste to a central facility where it is unloaded either directly or indirectly onto a transfer vehicle that will carry it to the ultimate disposal site. Transfer vehicles can transport solid waste at a lower per ton cost than refuse collection vehicles. A solid waste transfer operation becomes economically attractive when the costs of the transfer station plus the costs to transport the waste to the disposal site with a transfer vehicle are less than the costs to transport the refuse directly from route with the collection vehicles. The applicability of the solid waste transfer concept to the City of Aiken will depend upon the location of the disposal site in relation to the city.

Refuse haul costs and transfer facility operation costs were estimated for Aiken. The calculations associated with these estimates are presented in Appendix B. Based on capital and operation costs of existing facilities of similar size it is estimated that the current unit cost for a solid waste transfer facility in Aiken would be about $2.8/ton. It was estimated that the capital and O&M costs of a transfer vehicle for Aiken would be equivalent to $6.6/ton. It is also estimated that current refuse haul costs are about $0.50/ton-mile when using a refuse packer vehicle (assuming one person per vehicle). According to the cost estimates the minimum economical haul distance (break-even distance) using a transfer system in this case is about 19 miles. At distances less than the break-even

distance it is more cost effective to haul refuse with packer vehicles. It should be noted that the transfer cost estimates presented here are quite general and should only be used as economic indicators.

Comparative Economics of Landfill Disposal Options

The relative economics between operating a City landfill and utilizing the County landfill will have a major impact upon solid waste management decisions that the City of Aiken will be faced with in the future. The objective of this section is to present estimates of the relative economics between several of the solid waste management options which are available to the City of Aiken.

Table 3.1 presents an estimate of the costs associated with the present operation of the Aiken City landfill. The calculations used to develop the item costs are given in Appendix B. It is estimated that the total annual landfill costs are about $114,000 (1980$). Based on an estimated refuse production rate of 12,000 tons/year the landfill unit cost is approximately $9.5/ton.

Table 3.2 tabulates information concerning the relative economics between the presently available refuse hauling and landfill options. It has been assumed that the unit costs for landfilling at either the North Site or the West Site will be approximately the same as the cost for the present landfill. The disposal cost for the use of the County landfill has been presented as zero. This might be misleading, and the reason should be noted. There are real costs associated with operation of the County landfill, and the citizens of the City of Aiken pay a portion of these costs through their county property taxes. At present all the County landfill costs are paid from the property tax fund and no per ton or tipping fees are imposed. Unless the financing structure for the County landfill changes, the citizens of the City of Aiken will continue to pay a portion of the landfill's costs regardless of whether or not the City operates its own landfill. Thus the City of Aiken's contribution to the support of the County landfill does not enter into an economic comparison of the landfill options.

TABLE 3.1

ESTIMATE OF AIKEN CITY LANDFILL ANNUAL COSTS

ITEM	ESTIMATED ANNUAL COST ($ /Year)[1]
Land cost	6,000
Equipment capital cost	39,000
Direct operating cost[2]	12,000
Major maintenance	15,000
Utilities	2,000
Labor	25,000
Major Excavation[3]	15,000
Total	$114,000/year
Estimated unit cost[4]	$ 9.5/ton

(1) Cost estimate calculations are presented in Appendix B. Costs are expressed in terms of 1980 $.

(2) Fuel, oil, tires, lubricants, filters and other routine maintenance items.

(3) Trench excavation by outside contractor.

(4) Based on an estimate of 12,000 tons of refuse produced per year in Aiken.

TABLE 3.2

RELATIVE ECONOMICS OF LANDFILL DISPOSAL OPTIONS

Disposal Option	Estimated Disposal Cost ($/ton)[1]	Approximate Average Haul Distance (miles)	Estimated Haul Cost ($/ton)[1]	Haul and Disposal Cost ($/ton)[1]
Aiken City Landfill				
Present Site	9.5[2]	2.3	1.2[4]	10.7
North Site	9.5[2]	3.3	1.7[4]	11.2
West Site	9.5[2]	4.0	2.0[4]	11.5
Aiken County Landfill				
Haul with packer vehicle	0[3]	12	6.0[4]	6.0
Haul with transfer vehicle	0[3]	12	9.4[5]	9.4

(1) All costs expressed in terms of 1980 $.

(2) See Table 3.1 and Appendix B for cost estimates. Assumes landfill costs at North and West sites are same as present landfill costs.

(3) Aiken County landfill is operated from county property tax funds. Aiken city residents pay county taxes. Zero disposal cost is presented here since county property taxes will be paid regardless of disposal option selected.

(4) Assume $0.50/ton-mile cost for haul with packer vehicle. See Appendix B.

(5) Cost of transfer facility and vehicle. See Appendix B for cost estimates.

It has been estimated that the total cost for hauling and disposing of refuse in the City's landfill is about $10.7/ton. Assuming that the annual landfill costs remain about the same it is estimated that due to the longer haul distances, the unit costs would increase to about $11.2/ton and $11.5/ton for landfills located at the North and West sites respectively. It is probable that landfilling costs will increase in the coming years but the estimates are based on 1980 dollars to allow economic comparison. The costs associated with hauling the Aiken municipal refuse to the County landfill are also presented in Table 3.2. Cost estimates are given for hauling with packer vehicles as well as for the use of a transfer system. The estimated haul cost using packer vehicles is about $6.0/ton. This estimate is made assuming one person per vehicle. In cases such as this where the haul distance is relatively long a significant cost can be associated with allowing collection crews to accompany the vehicle driver to the landfill rather than perform some more productive activity. The estimated cost for hauling to the County landfill with a transfer system is about $9.4/ton; somewhat higher than the estimated packer vehicle haul cost.

Based on the comparative economic information presented here the following conclusions can be formulated.

- If the financing structure for the Aiken County landfill remains the same as it is at present, it will be more economical for the City of Aiken to haul its municipal refuse to the County landfill than to dispose of it in a City-operated landfill. It is reasonable to consider a change to the County landfill in the near future rather than when the City landfill is exhausted. This could reduce disposal costs and provide some back-up landfill capacity (in case it becomes attractive to reopen the City landfill).
- It appears that a refuse transfer system would not have economic advantages over hauling with collection vehicles if it is decided to dispose of refuse at the Aiken County landfill. However, a definite conclusion would require a detailed study of specific transfer station location sites and the relative economics of the two hauling options.

CHAPTER 4
MANURE AND LEAF DISPOSAL

The many City-owned and private landscaped areas in Aiken yield a large quantity of waste leaves. Also the four horse tracks and a number of stables within the town produce a considerable amount of horse manure. City of Aiken personnel believe that leaves and manure pose a significant disposal problem for the City. Currently most of the waste manure and leaves are placed in uncovered piles on the City landfill property. This method of disposal is in violation of South Carolina's solid waste disposal regulations and could be environmentally unsound (particularly in the case of manure). The objectives of this chapter are to investigate several acceptable disposal options for these wastes. No good information on the quantity of leaf and manure wastes is available so most of the discussion will, of necessity, be quite general.

The disposal/resource recovery options for leaf and manure wastes which could have applicability in Aiken are:

- o Proper Sanitary landfill disposal
- o Incineration
- o Composting

These options are discussed in the following sections of this chapter.

LANDFILL DISPOSAL

Most of the Aiken's solid waste is disposed of in a City owned and operated landfill. Various aspects of this landfill, future

landfill disposal alternatives, and landfilling in general have been discussed elsewhere in this report.

It is believed that proper sanitary landfilling must be considered a viable option for the disposal of leaf and manure wastes in Aiken. Proper landfill disposal of these wastes is at least as environmentally sound as landfill disposal of wet organic household wastes and is definitely preferable to the uncovered surface disposal presently being practiced in Aiken.

INCINERATION

Incineration can be used to dispose of leaf and manure wastes (note that incineration does not represent an "ultimate" disposal option; the resulting ash residues must be disposed of elsewhere). These types of wastes normally have a water content which is too high to allow them to be directly incinerated. It is usually necessary to pre-dry wetter wastes before incineration. Incineration is an energy intensive technology and if the waste must be pre-dried, the energy requirements can be increased. Energy requirements must be a serious point of consideration when evaluating waste disposal alternatives at the present time. Under present conditions landfilling is usually a more economically attractive disposal alternative than incineration in situations where landfill property is reasonably available.

It is concluded that incineration is not as practical as landfilling for disposal of leaf and manure waste in Aiken.

COMPOSTING

Composting is a process through which the quantity of an amenable waste can be reduced while the remaining fraction has value as a soil conditioner. Based on experiences at operating compost facilities it is likely that composting of a mixture of leaf and manure wastes is technically feasible for Aiken.

The Composting Process

Composting is the biochemical breakdown of waste organic matter. Tests have shown that manure can be reduced as much as 60% by dry

weight; 45% by volume. In addition to waste reduction, the aerobic action of microorganisms (bacteria, fungi, and actinomycetes) produce a substance suitable for use as a soil conditioner. Since composting is dependent on the bio-functions of the microorganisms, factors such as moisture, temperature, oxygen availability, pH, carbon to nitrogen ratio and particle size have an impact upon the process.

Moisture content is important for structural stability (in windrow composting) and to provide microorganisms with necessary water. In addition moisture content impacts upon oxygen availability in the compost. Too much water causes the compost to compact and decreases the amount of air present. This can cause anaerobic conditions and objectionable odors to be emitted. However, an adequate water supply is required to insulate the compost enough to maintain the necessary high temperatures which are needed for decomposition. It has been found that water concentrations should range between 40% and 60%, with 50% to 55% giving the best results for leaf and manure compost.

Composting temperature is a factor which is directly related to decomposition rate. As decomposition progresses, the temperature of the compost increases. As the process continues, different types of microorganisms dominate depending upon their preferred climate. The high temperature reached in composting bodies kill fly larvae, weed seeds and pathogens. Temperatures may reach 140°F to 160°F (60°C to 70°C) or higher. A drop in temperature can mean that the compost needs to be aerated, moistened or that the process is nearly completed.

Oxygen availability is an important consideration in composting. Without the proper amount of oxygen, anaerobic conditions will arise. Anaerobic decay is usually slower, often produces disagreeable odors and may not kill pathogens.

The pH is a factor that can alert operators to the presence of undesirable materials. Though decomposition occurs best at a neutral pH, small deviations will be seen in the normal process. In the first few days of decomposition the pH usually drops to 5 or below.

Thereafter the pH will rise, usually leveling off at 8.5 if aerobic conditions are maintained. Control of pH is rarely needed, as most aerobic decomposition will not alter the pH enough to hinder microbial growth.

The carbon to nitrogen ratio (C/N) is a relative measure of the carbon and nitrogen content available to composting microorganisms. In general, as composting progresses, the carbon content is reduced through CO_2 production while the quantity of nitrogen is maintained thus lowering the C/N ratio. The initial C/N ratio is a major factor contributing to the amount of time needed to complete the composting. As one might expect, the larger the C/N ratio the longer digestion requires. For example in windrow composting, a period of 9 to 12 days decomposition time is required for an initial C/N of 20; 10 to 16 days if the C/N is 30 to 50; and 21 days or more if the C/N is around 80. Leaves have a C/N ratio of about 80 while manure has a C/N ratio in the range of 10 to 20.

Another important factor in composting is particle size. Faster decomposition occurs when the particles are small because more surface area is available to the composting microorganisms.

Composting Methods

There are several composting methods available. Aerobic digestion can be performed in either closed or open systems. Closed systems consist of aerated tanks or rotating drums while open systems utilize trenches, pits, or windrows. The closed systems (such as digesters) usually require a large capital investment.

Windrowing is a composting method which has been used with success in the past. The material to be composted is arranged in long piles (windrows). Aeration and mixing can be accomplished in place by a front end loader, a clamshell bucket on a crane or a turner that straddles the windrow and mixes it using a rotating drum with teeth. Turning should occur twice a week to efficiently aerate the compost. In wet weather, windrows may be turned more often to release moisture. However, too frequent mixing can lower the temperature of the compost. Moisture content should be checked periodically and

adjustments made if necessary. If rainfall is interfering, some type of shelter can be constructed. Windrow composting of manure requires approximately 6 weeks in the field and about 2 weeks in a drying shed. At this point the compost is ready for use as a soil conditioner. Further finishing such as grinding and pelletizing (for agricultural and large-scale uses) may be desirable. Screening will probably not be required as leaves, small limbs and manure should all be completely decomposed. A storage area will generally be required for the finished compost.

Composting plants are potential sources of offensive odors and fly and rodent breeding if not properly operated. With good housekeeping habits, however, these problems can be minimized. Insecticides and poisons can eliminate existing flies and rodents, while the high temperatures reached in the windrows and the denial of hiding places should discourage future pests. Aerobic conditions should be maintained in the windrows to minimize any odor problems.

Economics of Composting

As with all refuse disposal and/or resource recovery methods, there are certain costs associated with composting. A rough cost estimate for a windrow composting facility sized to handle 12 wet ton/day of waste on a year-round basis has been made (see Appendix B). Though the quantity of leaf and manure waste generated in Aiken is not known, it is estimated that the maximum daily production rate does not exceed 12 wet ton/day. It should be remembered, also, that leaf and manure production in Aiken is seasonal and it is likely that the year-round rate is significantly less than 12 wet ton/day. It was estimated that the unit composting cost would be about $15/ton if 12 wet ton/day were composted.

It has been estimated that waste disposal at the City of Aiken landfill costs about $9.5/ton (see Appendix B). However if one ton of manure and leaf waste was composted and 45% volume reduction was achieved the total disposal cost would be:

Composting cost	$15
Cost of landfilling compost	$ 5
Total disposal cost	$20

It can be seen that the combined cost of composting and landfilling the compost is much more than the cost of landfilling the non-composted waste ($9.5). In fact for this concept to become economically feasible the unit cost for composting would have to be less than $4.5/ton. This is considerably lower than the typical unit cost for large facilities that have advantages due to economies of scale. Thus, the composted material would have to be marketed to make composting an economically feasible process for Aiken.

SUMMARY

Based on the material presented in this chapter the following conclusions have been formed.

- Landfill disposal is a technically feasible option for the disposal of leaf and manure wastes in Aiken.
- Incineration with a pre-dry step is a technically feasible alternative for disposal of leaf and manure wastes in Aiken. However it is doubtful that incineration can compete with landfilling from an economic point of view.
- The leaf and manure waste produced in Aiken would probably produce a good quality compost with value as a soil conditioner (especially if the wastes are mixed). However, economics dictate that composting of the leaf and manure wastes is not feasible for waste volume reduction alone. It would cost more to compost the wastes and landfill the compost than it would to landfill the non-composted material. To make composting feasible for Aiken it will be necessary to apply the compost to some economically productive use (sale of the compost on the open market or use of the compost to reduce City of Aiken soil conditioner costs). A survey of the local market for compost has not been made.

CHAPTER 5
MATERIALS RECOVERY

The objective of this chapter is to make a preliminary assessment of the feasibility of a materials recovery program which could be coordinated with the solid waste management system in Aiken. A resource recovery program in Aiken could be directed toward a reduction in solid waste volume by materials reclamation. The possibility of energy recovery from solid waste was eliminated during the Phase I study due to the apparent lack of a sufficient market. The following sections of this chapter will discuss basic materials separation methods and a preliminary area market survey.

MATERIALS SEPARATION TECHNIQUES

Currently there are two basic methods in common use for separating and gathering reclaimable materials from municipal refuse:

- o Centralized facilities for materials separation.
- o Source separation by refuse producers.

The method chosen to recover materials in a given situation primarily depends upon:

- o The quantity of recyclable materials in the waste stream.
- o The revenues available from marketing of the reclaimed wastes.
- o The costs associated with the materials separation method.

Centralized Materials Separation

Centralized materials separation involves manually or mechanically segregating the mixed solid waste stream at a central facility.

The marketable materials are stored for shipment to buyers while the non-salable portion of the waste is hauled to the refuse disposal site. The manual separation of materials on a large scale is quite expensive and can involve health hazards for working personnel.

The mechanical methods which are currently being used for materials separation include magnetic separation (recovery of ferrous metals), air classification (separation of waste into components by density) and froth flotation (separation of glass). Materials separation facilities will commonly use one or more of these technologies preceded by a refuse shredding device. These methods for centralized materials separation will be referred to as "high technology" methods for the purposes of this report.

Centralized high technology facilities for mechanical separation of materials require substantial capital investment. Based on information obtained for 20 facilities that were operating, under construction, or being planned in 1978, the average capital cost was about $24,000 per TPD capacity (The range of the TPD unit costs was $5,000-$75,000). The capacities of these facilities ranged from 150 to 3000 TPD. Based on an estimated commercial and residential solid waste production rate of 32 TPD for the city of Aiken (7-day basis) and a unit capital cost of $24,000 per TPD capacity, it can be estimated that a centralized mechanical materials separation facility would require an initial expenditure of about $800,000 (order of magnitude estimate). However, due to economies of scale and the relatively low waste production rate in Aiken, the installation could cost much more.

Table 5.1 presents estimates of the quantities of recyclable materials which could be recovered from the Aiken solid waste stream by high technology methods. Also shown is an estimate of the gross revenue which could be generated from the sale of the recovered material (revenue per ton was determined from a market survey which will be discussed later in this chapter). The estimates presented in Table 5.1 show that the maximum gross revenue which could be generated

TABLE 5.1

ESTIMATED RECYCLABLE MATERIALS RECOVERY USING HIGH TECHNOLOGY METHODS

	Portion of Solid[1] Waste Stream %	Estimated Quantity in[2] Aiken Solid Waste Stream (ton/wk)	Maximum Amount Recoverable[3] by High Technology Method %	Maximum Amount Recoverable From[3] Aiken Solid Waste (100 Ton/Year)	Recovered Material[4] Value ($/Ton)	Maximum Gross Revenue Generated ($/Year)
Glass	9	20	60	6.2	30	19,000
Ferrous Metal	4	9	100	4.7	19	9,000
Aluminum Cans	1	2	90	0.9	500	45,000
					MAXIMUM TOTAL REVENUE =	$ 73,000/

(1) From "Refuse Report", International City Management Association, July - September Issue, 1978, Volume 4, Number 3.

(2) Based on an estimated 226 ton/week commercial, household and landscape refuse collected in Aiken.

(3) From "1980 Sanitation Industry Yearbook", Solid Wastes Management, 17th Edition, 1980.

(4) Based on a May 1980 market survey done for the pruposes of this study.

(5) Gross revenue from sale of material. Does not reflect costs associated with collection, separation or transport of materials to buyer.

from a materials recovery program in Aiken is approximately $73,000/yr. This does not allow for costs associated with the collection, separation and transport of recovered materials to buyers. It is unlikely that the relatively small amount of revenue which could be generated from a materials recovery program in Aiken could justify the high capital and operating costs of a centralized high technology separation facility.

Source Separation

Source separation is a method of separating marketable materials from solid waste which can be successful in smaller communities. The idea is to motivate the refuse producer (householder, retailer, etc.) to separate the marketable materials from the rest of the solid waste as it is being discarded. An example of this technique would be for a household to place aluminum cans into one bag, newspaper into a second bag, and all other refuse into a third bag. On collection day the segregated wastes are collected and placed in different compartments of the refuse collection vehicle or picked-up by separate vehicles. The marketable materials are recovered and stored at a central location for shipment to buyers. The non-salable refuse is hauled to the disposal site.

Source separation efforts can be relatively inexpensive to operate but require public support and participation in order to be successful. Some techniques that have been used to inspire public cooperation are listed below:

1. Informing the public that the revenues derived from the materials recovery program will be used to help control solid waste collection costs and thus minimize rate increases.
2. Using revenues for highly visible civic improvements (public park improvements, etc.).
3. Providing the home owners with color-coded refuse bags for the different materials to be separated. This makes source separation more convenient for the public and the collectors.

4. Promoting the reclamation project via radio, television, and newspaper advertisements
5. Passing of City ordinances that require people to separate their refuse.

Figure 5.1 shows a card (front and back) which is being used to promote a newspaper recycling program in DeKalb County, Georgia. The card has been distributed to county residents with their garbage bills.

The combinations of techniques that have successfully been used to promote source separation programs vary from application to application. Before instituting a source separation program, a study of incentive techniques that have been used in other communities should be made. A source separation program for Aiken should be planned based on the findings of this study and an assessment of pertinent physical parameters and public attitudes.

Past experience has shown that it usually takes continued effort over a relatively long period of time to attain a high level of public participation in a source separation program. Figure 5.2 shows the level of public participation in a newspaper recycling program over a period of time. In this example it required about four years to reach a point where 80% of the public was involved in the program. The important thing to note here is that when planning a source separation program, the organizers must be prepared to maintain their efforts over an extended period of time even though initial public support may be low and discouraging.

It is believed that of the two materials separation techniques discussed here the most practical approach to materials recovery for the City of Aiken is source separation.

PRELIMINARY MARKET SURVEY

A preliminary market survey was performed. Purchasers of recovered materials in South Carolina and Georgia were contacted. The results of this survey are presented (by material type) in the following subsections.

PROMOTIONAL ADVERTISEMENT FOR NEWSPAPER RECYCLING PROGRAM IN DEKALB COUNTY,GEORGIA

DeKalb County Newspaper Recycling Program

Three Ways to Recycle Your Newspaper:

1. Curbside Collection: Tie newspapers in bundles or place them in a grocery sack? Put at the curb on your regular trash collection day.
2. Deposit your newspaper in the specially marked containers at major shopping centers in the County.
3. Support newspaper drives held by churches, schools and charitable organizations.

**Please include only newspaper—NO MAGAZINES!*

Good Reasons to Recycle:

Landfill space is scarce and expensive. Each ton of newspaper recycled saves three cubic yards of landfill space.

Newspaper can be recycled several times. Use of recycled fiber conserves forest resources and energy.

Revenues from sale of your used newspapers go into the Sanitation Fund to help defray the costs of garbage collection.

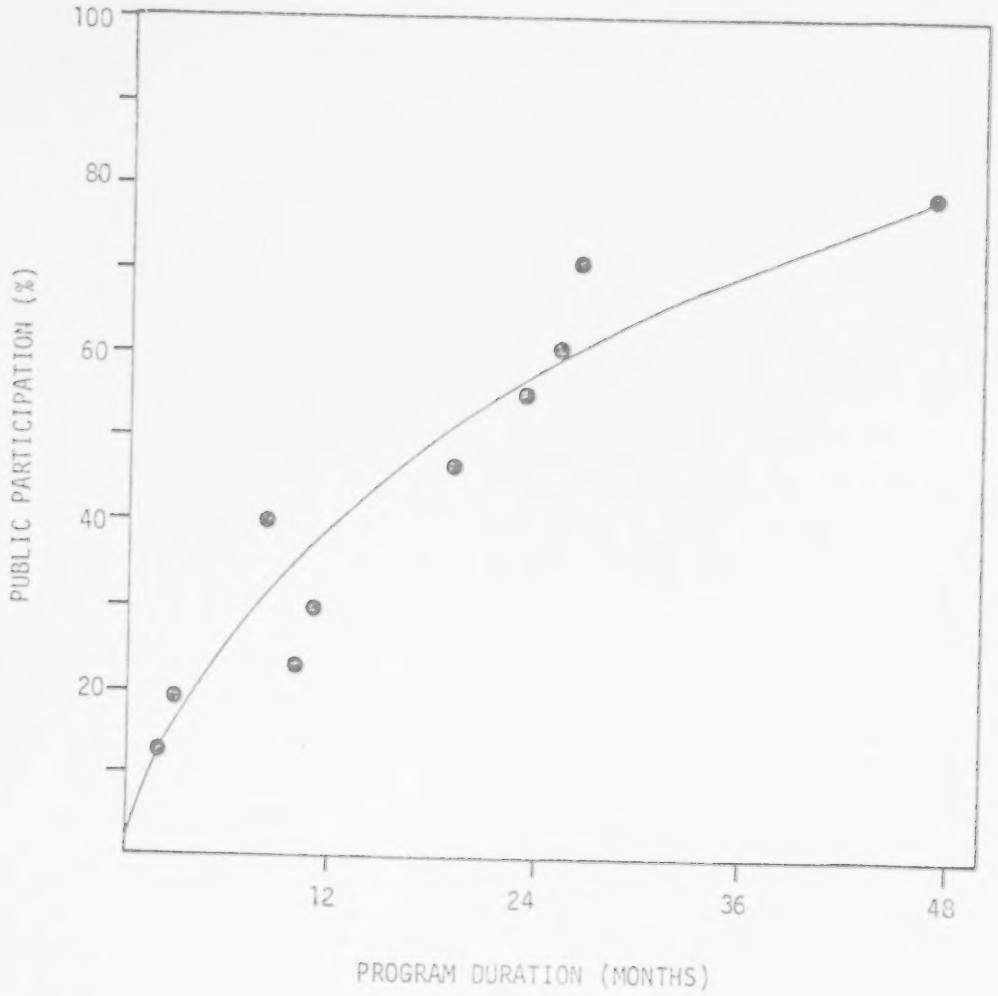
Remember:
If you do place your newspaper at the curb, it becomes County property and only the County may collect it. If you see anyone else taking it, please call the County Sanitation Department at 294-2100.

CARD WAS DISTRIBUTED WITH RESIDENTIAL WATER/SEWER/GARBAGE BILL.

USED BY PERMISSION OF HENRY FOGG, DEKALB COUNTY SANITATION DEPARTMENT.

FIGURE 5.2

PUBLIC PARTICIPATION IN A NEWSPAPER RECYCLING PROGRAM*



* P.A. Vesilind, D. Warner, "Cities Should First Consider the Various Resource Recovery Systems", Solid Wastes Management, May 1978, page 63.

Paper

Two types of potential buyers for reclaimed paper were contacted. One type is firms which are in the business of buying and selling waste paper (secondary market), and the other type consisted of paper mills which buy waste paper for their own use (primary market).

Several secondary buyers were contacted in Atlanta and Augusta. The ACME Box and Paper Salvage Company was representative of the prevailing Atlanta market. The dealers indicated a willingness to buy waste paper from Aiken. No shipping is provided by the stock dealers. There is no requirement that the reclaimed paper be baled, but it must be strictly segregated into newspaper, corrugated and mixed (magazines, office, etc.) classifications in order to receive the highest price. If any mixing of paper types occurs, the mixed paper price will be paid. Table 5.2 gives the prices currently being paid by the Atlanta and Augusta dealers. Also included is the haul distance and the net revenue. The net revenue is the price paid for the paper less the cost for hauling the paper to the buyer (does not account for other costs associated with collecting, separating and storing the paper). Currently the price paid for all types of paper in Atlanta is higher than the price being paid in Augusta but due to the shorter haul distance it could be economically attractive to sell some of the paper types in Augusta. The net revenue for mixed paper and newspaper is higher from the Augusta market while the net revenue for corrugated paper and computer cards is higher from the Atlanta market. If a paper recycling program is instituted in Aiken it would be advisable for the operating personnel to establish contacts in several market areas and monitor current price fluctuations closely. This could help to optimize the net revenues derived from the program.

The Tally Company in Aiken is in the business of buying and selling recyclable materials. Currently they pay $10/ton to private citizens for newspaper. The company accepts mixed paper but does not pay for it due to the low current market price. It is possible that if a paper recycling program is operated in conjunction with the Aiken solid waste collection program that the Tally Company could function as a broker.

TABLE 5.2

STOCK DEALER WASTE PAPER PRICE SUMMARY

	AUGUSTA GA MARKET[1]			ATLANTA, GA MARKET[2]		
PAPER TYPE	June 1980[3] Price ($/Ton)	Haul Distance[4] (miles)	Net Revenue[5] ($/Ton)	May 1980[3] Price ($/Ton)	Haul Distance[6] (miles)	NET REVNEUE[5] ($/Ton)
Mixed	3	20	0.5	15	160	NE[7]
Newspaper	35	20	33	40	160	20
Corrugated	20-25	20	18-23	45	160	25
Computer Punch Cards	140	20	138	200	160	180
Computer Print-Out	50	20	48	--	160	--

(1) Price information provided by Consolidated Fibers, Inc., Augusta, GA.

(2) Price information provided by Acme Box and Paper Salvage Co., Atlanta, GA.

(3) Price paid for paper delivered to buyer's location.

(4) Approximate road distance from Aiken, S.C. to Augusta, GA.

(5) Calculated as price paid for paper minus the cost of hauling the paper to the buyer. Haul cost was estimated at $0.125/ton-mile. Does not account for costs associated with collecting, storing or segregating the waste paper.

(6) Approximate road distance from Aiken, S.C. to Atlanta, GA.

(7) NE: Not economically feasible; haul cost exceeds price paid for paper.

During the past year the waste paper market has been relatively stable, but the dealers suggested that when planning a recovery program the organizers should be prepared for occasional minimum prices of $25/ton for corrugated, and no market at all for newspaper or mixed paper.

Three primary paper buyers were contacted. One of these firms (Kimberly Clark, Beech Island, S.C.) buys only through intercompany purchases. At present their requirements for waste paper are shipped from Wisconsin in rail car quantities. The second firm (Container Corporation of America, Chattanooga, TN) purchases reclaimed paper weekly at their plant. The seller is responsible for shipment of the paper. The prices currently being paid are given in Table 5.3. Also listed is the haul distance and net revenue. Since the haul distance is great the only type of paper which might be economically transported to this buyer is computer cards. The third company (Deerfield Specialty Papers, Inc., Augusta, GA) occassionally buys waste paper but is not doing so at present.

Glass

Four buyers of reclaimed glass were contacted. Three are primary buyers and are in the business of glass container production (Indian Head Inc., Laurens, South Carolina; Ball Co., Asheville, North Carolina; Owens-Illinois, Inc., Winston-Salem, North Carolina). The reclaimed glass buying policies of all these companies were essentially the same:

- Only container glass will be purchased (jars and bottles)
- Glass must be relatively clean and empty (no caps)
- Glass must be separated by colors
- Glass must be delivered to the plant.

Table 5.4 summarizes the price information obtained from the glass recyclers contacted. Also given is the approximate haul distance and the net revenue. It can be seen that for two of the three buyers there is a positive net revenue.

The fourth contact was a secondary glass buyer (the Tally Company that was mentioned in the previous section). Currently the Tally Company buys glass from private citizens for $5/ton. The company

TABLE 5.3

PAPER MILL WASTE PAPER PRICE SUMMARY

Paper Type	May 1980 Price(1) ($/Ton)	Haul Distance(2) (Miles)	Net Revenue(3) ($/ton)
Mixed	19	325	-22
Newspaper	31	325	-10
Corrugated	35	325	-6
Computer Punch Cards	160	325	119

(1) Information for sale to Container Corporation of America (price paid for paper delivered to Chattanooga).

(2) Approximate driving distance from Aiken, South Carolina to Chattanooga, Tennessee.

(3) Net revenue received per ton after transport. Does not account for costs of collection, separation or storage. Assumes $0.125/ton-mile for transport.

TABLE 5.4

PRIMARY BUYERS OF RECLAIMED GLASS

Location[1]	May 1980 Price ($/Ton)	Haul Distance[2] (Miles)	Net Revenue[3] ($/ton)
Indian Head, S.C.	30	100	18
Ball Co., N.C.	30	200	5
Owens-Illinois, N.C.	30	300	-8

(1) All Buyers require:

- Only container glass (no flat glass, mirrors, etc.)
- Glass must be relatively clean, empty and without caps.
- Glass must be separated by colors (clear & green.)
- Glass must be delivered to the plant.

(2) Approximate driving distance from Aiken, S.C. to each reclaimed glass buyer.

(3) Net revenue received per ton after transport. Does not account for costs of collection, separation or storage. Assumes $0.125/ton-mile for transport.

requires caps to be removed from the glass but does not require labels to be removed. The company encourages the sellers to separate the glass by color but does not absolutely require it.

Aluminum

Four types of scrap aluminum buyers in the Georgia-South Carolina area were contacted; aluminum producers, aluminum smelters, large aluminum companies with recycling divisions and a recovered materials broker.

None of the producers contacted use scrap aluminum. The secondary smelters buy only alloy grade aluminum (structural aluminum, etc.) which is not normally found in significant quantities in municipal refuse.

The Alcoa Aluminum Company is one of the larger aluminum companies which buys the type of aluminum which would be obtained from a municipal recovery program (i.e. cans) . At this time, they do not have any recycling centers in the area in question and would require that the scrap be baled and transported to their plant in Atlanta, Georgia. They currently pay $620 to $640/ton for scrap aluminum cans.

The Reynolds Aluminum Company has a recycling center in Augusta, Georgia. The person contacted here expressed an interest in participating in a materials recovery program with the City of Aiken. They would be willing to send a truck to Aiken to pick-up loads of scrap aluminum in 2,000 lb lots (primarily cans). If the recovery program in Aiken was able to collect significant amounts of scrap on a consistent basis, a regular pick up could be arranged (once per month, once every three months, etc.). If not, the recovered aluminum would be picked up as needed. This flexibility could be attractive during the start-up period of a materials recovery program when public participation is low and quantities of aluminum that will be available at any given time are uncertain. The scrap would not have to be baled, but should be boxed or bagged. The price paid for aluminum by this firm varies depending on how far they have to haul it and market price; but currently, they are guaranteeing a minimum of $500/ton. The aluminum

is taken to the recycling center where it is shredded and separated from any other debris. Payment is made on the actual amount of aluminum in the shipment after separation.

The Tally Company of Aiken buys recovered cans and structural aluminum. Currently they are paying private citizens $520/ton for mixed scrap aluminum.

Ferrous Metal

Several steel mills were contacted. All of these mills are in the business of producing steel, at least partially, from scrap ferrous metals. In all cases the mills buy only large quantities (minimum of 50 tons) of shredded and graded scrap metal. They deal with large scrap dealers who have the facilities to shred and grade scrap that they buy from smaller dealers or individuals.

Two large steel scrap dealers were contacted. The dealers are currently buying relatively clean segregated scrap steel which is delivered to the plant. Table 5.5 gives the price information obtained from the Augusta, Georgia and Darlington, South Carolina dealers for each type of scrap. Also shown is the haul distance and net revenue. Currently the Darlington dealer is offering higher market prices for all types of scrap but due to the shorter haul distance Aiken would produce more revenue by hauling some of the scrap to the Augusta dealer. It should be noted, however, that the scrap steel market can vary dramatically. At present market prices are dropping because of slumps in the auto industry.

Sometimes the most cost effective method to separate scrap steel is to designate an area for disposal of large steel items. As private users deposit large scrap steel items (washing machines, etc.) they can be accumulated for transport to the recycler. In this way collection and separation costs are minimal. The City of Aiken would have to provide a storage area in which to accumulate ferrous metal for intermittent truck pick-up (could be located on landfill property). Also a business relationship with a scrap hauler and buyer would have to be established. It is doubtful that the program could justify purchase of loading or transport equipment by the City of Aiken.

TABLE 5.5

SCRAP METAL DEALER PRICE SUMMARY

	Augusta, Ga. Market[1]			Darlington, S.C. Market[2]		
Metal Type	June 1980 Price[3] ($/ton)	Haul Distance[4] (miles)	Net Revenue[5] ($/ton)	May 1980 Price[3] ($/ton)	Haul Distance[6] (miles)	Net Revenue[5] ($/ton)
Automobiles	30	20	28	40	125	24
Appliances	22	20	20	36	125	20
Miscellaneous	15	20	13	25	125	9

(1) Price information provided by Dixie-Land Iron and Metal Company, Augusta, Ga.

(2) Price information provided by Darlington Metals, Inc., Darlington, S.C.

(3) Price paid for paper delivered to buyer's location.

(4) Approximate road distance from Aiken, S.C. to Augusta, Ga.

(5) Calculated as price paid for steel minus the cost of hauling to the buyer. Haul cost was estimated at $0.125/ton-mile. Does not account for costs associated with collecting, storing or segregating the scrap metal.

(6) Approximate road distance from Aiken, S.C. to Darlington, S.C.

SUMMARY

The following conclusions are offered regarding materials reclamation in Aiken.

- Based on an estimate of the quantity of materials available for recycling, it is not likely that a centralized "high technology" materials separation facility could be justified economically for Aiken.
- It is possible that a source separation program can be successfully operated in Aiken. It should be noted, however, that a successful source separation program requires a high level of continued effort on the part of the organizers and operators.
- A preliminary survey indicates that markets for recovered paper, glass, aluminum and ferrous metal exist for Aiken. The economically successful recovery and sales of any of these materials will be dependent upon the costs associated with collection, separation and transportation of the materials as well as the existing market conditions (in some cases highly variable).

CHAPTER 6
SOLID WASTE COLLECTION

The objective of this chapter is to describe and evaluate the Aiken solid waste collection program. Concepts which could be applied in Aiken to increase system productivity and cost efficiency will also be discussed.

EXISTING SOLID WASTE COLLECTION PROGRAM

Residential and commercial solid waste is collected and disposed of by the City of Aiken. The collection program can be divided into the following three areas:

- o Household refuse (garbage) collection
- o Brush, leaf and miscellaneous bulky refuse (trash) collection
- o Commercial collection

The City of Aiken does not presently perform collection from large industrial facilities.

Garbage Collection

Garbage Collection System Description

The City of Aiken collects garbage from residents who live within the City limits. The level of service provided is as follows:

- o Twice per week collection
- o Backyard refuse placement
- o Can and/or bag containerization

At present the Aiken Garbage Collection System (AGCS) consists of a total of 4 residential collection crews. Each crew is responsible for garbage collection on two routes (note that route, when

mentioned here, refers to the area serviced by one crew in one collection day). On Monday and Thursday garbage is collected from one route; on Tuesday and Friday from the other route. On Wednesday each crew is responsible for general cleanup on both of its routes.

Most of the AGCS crews are made-up of four persons each. However, some of the crews consist of five or even six persons part of the time. One person is responsible for driving the collection vehicle and acts as a crew chief (driver). The other workers are responsible for loading refuse into the collection vehicle (walkers). As a rule drivers do not regularly help load refuse. However, during observation of the crews it was noted that the drivers do help load refuse into the packer vehicles from time to time. At present the drivers are paid at a higher rate than the walkers.

The AGCS uses rear load type packer vehicles for residential solid waste collection. Each crew is assigned a packer and uses the same vehicle regularly unless there is an equipment failure. All of the collection vehicles have nominal refuse capacities of 20-cu yd.

The AGCS is not operated with an employee incentive program at present. The collection personnel work a nominal 8-hour day.

Garbage Collection System Performance

The objective of this section is to present the results of a productivity and cost efficiency analysis of the AGCS which was done as a part of this study.

Productivity of municipal refuse collection systems is often expressed in the following terms:

- o weight of refuse collected per crew per hour
- o service provided per crew per hour

Common variations include per crew member and per walker expressions for productivity.

Weight collected productivity measurement (ton/crew-hr, etc.) requires weight records for the full refuse vehicles. Due to the fact that refuse production rates can be highly variable over short periods it is necessary to collect a considerable number of weight measurements over an extended period of time to develop a meaningful data base. A task of this magnitude was beyond the scope of this study.

Productivity can be measured in other ways and weight information is not necessary to achieve the objectives of this analysis.

Service provided productivity will be used as the basic measurement of productivity. These measurements can be made much more easily and more accurately over a short period of time. The basic unit of productivity which will be used here is "pick-ups/ crew-hr." This is an expression of the average number of pick-ups each crew is making per on-route hour. It is important to remember in this case each home is serviced twice per week (homes served/ crew-hr will be one half the pick-ups/crew-hr). To avoid confussion pick-ups/crew-hr, pick-ups/crewmember-hr or pick-ups/walkerhr will be used exclusively here.

Two basic pieces of information are needed to determine system productivity:

- o The average productive time spent on route (daily or weekly)
- o The average total number of pick-ups made during this time period.

In this case the necessary time measurements were made by having the collection vehicle drivers keep daily log sheets. A blank log sheet is shown as Table 6.1. The data was collected daily for a four-week period. From the completed data sheets it was possible to calculate the amounts of time that were spent on travel to and from the route, travel to and from the landfill, breaks and on-route collection. The drivers also noted mileages for the various activites. The data sheet also has blanks for house counts and fuel usage, but this information was not recorded in most cases. The number of homes being served on each route were determined from two maps which were provided by the City of Aiken. One map showed the boundaries of the individual routes and the other showed the number of residences (block-by-block).

Table 6.2 shows the results of the AGCS productivity analysis. Also shown is the basic data which were used to calculate the productivities of the collection crews. Based on this analysis it is estimated that the productivity of the AGCS ranges from 69 to 149

TABLE 6.1

GARBAGE COLLECTION SYSTEM DATA SHEET

CITY OF AIKEN, SOUTH CAROLINA

_____,1980
Date

Route_____ Driver/Supervisor_____

Crew_____ Walker _____

_____

_____

Activity	Time	Mileage
Leave Shop	_____	_____
Arrive on Route	_____	_____
Stop for Break	_____	_____
Resume Collecting	_____	_____
Stop for Lunch	_____	_____
Resume Collecting	_____	_____
Stop for Break	_____	_____
Resume Collecting	_____	_____
Leave Route	_____	_____
Arrive at Landfill	_____	_____
Leave Landfill	_____	_____
Arrive at Shop	_____	_____

Homes Served (Stick Count)_____ Gas Fill-up:

_____ Gallons Gas_____

_____ Gallons Diesel_____

_____

TABLE 6.2

AIKEN GARBAGE COLLECTION CREW PRODUCTIVITY

Crew	Route[1]	Average Time (hr/day)[2] Productive[3]	Non-productive[4]	Total[5]	No. Homes[6] served	Average Crew Size	Productivity[7] Pick-ups/crew-hr	Pick-ups/crewmember-hr
MS-21	M-T	6.6	0.4	7.0	700	4.0	106	27
	T-F	3.9	0.2	4.1	580	4.0	149	37
MS-22	M-T	7.7	0.4	8.1	830	4.0	108	27
	T-F	5.8	0.3	6.1	640	4.1	110	27
MS-23	M-T	7.5	0.8	8.3	520	4.1	69	17
	T-F	5.6	0.3	5.9	610	4.2	109	26
MS-25	M-T	6.5	0.4	6.9	850	4.6	131	28
	T-F	3.2	0.3	3.5	270	4.6	84	18

System Average Productivity: 10,000 pick-ups/93.6 crew-hr = 107 pick-ups/crew-hr
10,000 pick-ups/390.9 crewmember-hr = 26 pick-ups/crewmember-hr

(1) M-T = Monday-Thursday route; T-F = Tuesday-Friday route.

(2) From data taken by collection crews during April and May, 1980.

(3) On-route collecting time.

(4) Time spent on breaks, travel to/from route and travel to/from landfill.

(5) Total from time crew leaves motorpool until crew returns to motorpool.

(6) Based on information provided by City of Aiken personnel.

(7) Based on on-route time.

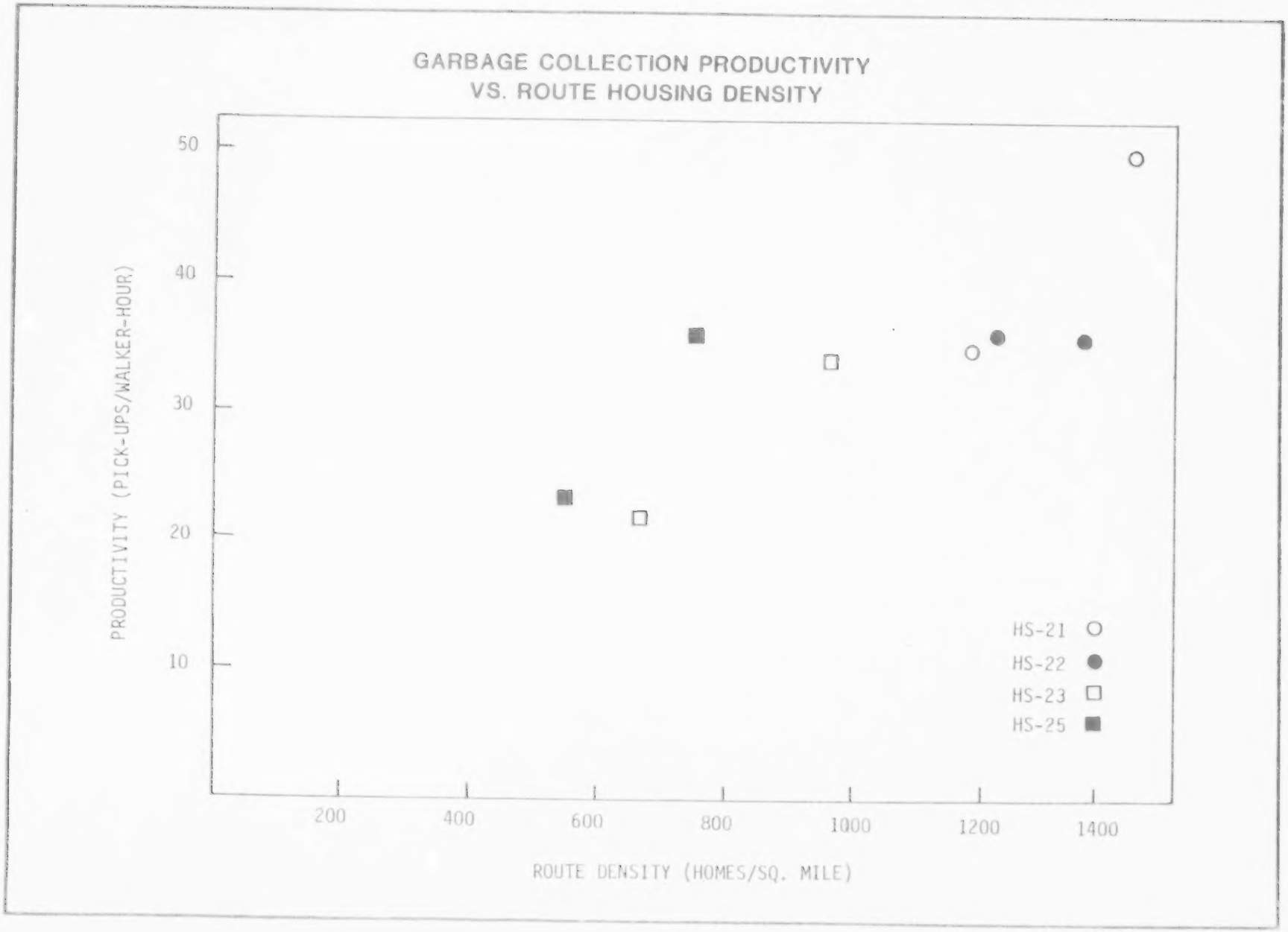
pick-ups/crew-hr with the system-wide average being about 107 pick-ups/crew-hr. The average per crewmember productivity ranges from 16 to 37 pick-ups/hr and averages about 26 pick-ups/hr.

The variability in the per crew productivities that were measured in Aiken is due partially to a variability in per walker productivity between the crews and partially to a difference in the sizes of the crews. The variability in per walker producti- that was observed in Aiken could be due to one or both of the following factors.

- o An actual difference in the rate at which the individual walkers are working.
- o Physical differences between the routes that affect per walker productivity.

Though the first factor cannot be ruled out altogether, observations of the AGCS crews did not reveal drastic differences in the speed with which the individual walkers were working. It was decided to determine if there was some physical difference between the routes that could have a major impact upon the per walker productivity. One of the important physical characteristics affecting productivity is the housing density of a given route. This factor affects the size of the yards and distance between houses in a residential area. A major time consuming activity for the walkers in a backyard collection system is travel between the packer vehicle and the refuse placement location. As yards become larger this activity requires more time and effort. The housing densities for the eight AGCS routes were measured. Figure 6.1 shows a plot of route density versus per walker productivity for the system. It can be seen that three of the four crews performed more productively on their route with the higher housing density. Also there was a general system-wide increase in productivity with increasing housing density. It can be concluded that housing density does have an impact on garbage collection productivity in Aiken and that the crews are more productive in the areas of town with higher housing density.

There is another noteworthy fact that was observed during the productivity analysis. The daily time which was being spent on collection and off-route collection related activities during the data


GARBAGE COLLECTION PRODUCTIVITY
VS. ROUTE HOUSING DENSITY
PRODUCTIVITY (PICK-UPS/WALKER-HOUR)
50
40
30
20
10
200
400
600
800
1000
1200
1400
ROUTE DENSITY (HOMES/SQ. MILE)
HS-21
HS-22
HS-23
HS-25

gathering period was not well balanced between the four AGCS crews (see Table 6.2). The HS-22 and HS-23 crews averaged about 7.1 hr/day each while the HS-21 and HS-25 crews averaged only 5.5 hr/day and 5.2 hr/day respectively. This situation can be credited to differences between the number of homes on the routes (ranges from 270 to 850 homes/route) and the previously discussed differences in productivity. It is believed that this situation is undesirable from a system performance point of view and is inequitable to the individual collection workers.

Evaluation of Garbage Collection System Performance

The relative productivity of a given refuse collection system can be evaluated by comparison with the productivities of other operating systems. This approach shall be taken here.

In 1975 the U.S. EPA published the results of a detailed study of 11 municipal collection systems ("Residential Collection Systems", EPA/530/SW-97c.1, March, 1975). The study monitored day to day operation of the systems for a one year period and evaluated year-round productivity. The following quotation from the summary section of the study report sums up the goals and achievements of the study. "A concerted effort was made to select only highly productive systems for this study. Also, the most productive four routes of each system were selected for the study. The study data, then, represent reasonable productivity targets for similar systems. It is expected that this information will give residential solid waste collection managers everywhere a valuable tool for appraising the productivity and cost efficiency of their operations." This study represents one of the best efforts to date on residential solid waste collection productivity analysis.

None of the systems studied by the EPA are directly comparable to the AGCS. Some of the systems collect twice per week, but these systems use curb side placement. The two EPA study systems that collect from the backyard pick-up only once per week. Though none of the systems can be used to make a direct comparison it will be possible to use the study information to give a general indication of the relative productivity of the AGCS.

As previously stated, two of the EPA study systems collect from the backyards of the homes that they serve (these systems will be referred to as Systems A and B). It was also noted that these systems collect only once per week. Thus, at each pick-up the refuse for an entire week is collected. This fact should tend to make a one pick-up per week system less productive (on a per pick-up basis) than a twice per week system where only a portion of each household's refuse is collected with each pickup. The previous statement is true only when considering productivity on a pick-ups/hr basis; it does not apply when considering homes served/ hr productivity.

Table 6.3 shows the basic operating parameters for the AGCS as well as Systems A and B. It can be seen that, in a number of ways, the systems are similar. However, they do differ based on crew size, incentive system and collection frequency.

Table 6.4 tabulates the productivities of the AGCS and Systems A and B. The once per week collection productivities shown for Systems A and B were measured during the EPA study that was previously mentioned. The twice per week productivities for Systems A and B were estimated. It has been found that, in general, an increase from once per week to twice per week collection requires an increase of about 50% in the collection crew labor force. This factor was used to make the twice per week collection productivity estimates for Systems A and B.

It can be seen from the information presented in Table 6.4 that the AGCS is more productive than the other systems on a per crew basis. This is to be expected since the AGCS averages more than twice the number of personnel per crew than the other systems. When considering per crewperson productivities it can be seen that the AGCS is more productive than System B but not as productive as System A for once per week collection. However, when the productivities of Systems A and B are adjusted for twice per week collection both Systems A and B are more productive than the AGCS on a per crewmember basis. Though System A is more productive by a significant amount (81%), System B is only about 15% more productive.

TABLE 6.3

OPERATING PARAMETERS FOR AIKEN AND COMPARISON SYSTEMS

System[1]	Operating Agency	Crew[2] Size	Incentive System	Equipment[3] Type	Collection Frequency	Collection Methodology	Storage[4] Container	Container Placement
Aiken	Public	4-5	none	Rear loader	2/wk	Tote barrel	B&C	Backyard
A	Public	2	task	Rear loader	1/wk	Tote barrel	B&C	Backyard
B	Public	2	none	Rear loader	1/wk	Tote barrel	B&C	Backyard

(1) Data for systems A and B taken from "Residential Collection Systems; Volume 1", EPA/530/SW-97c.1, U.S. EPA, 1975

(2) Includes drivers and walkers

(3) Packer capacity varies

(4) B&C = bags and cans

TABLE 6.4

PRODUCTIVITY FOR AIKEN AND COMPARISON SYSTEMS

System[1]	Productivity: Pick-ups made: per crew-hr[2]	Productivity: Pick-ups made: per crewperson-hr[2]
Aiken [3]	107	26
System A		
Once per week[4] collection	72	35
Twice per week[5] collection	96	47
System B		
Once per week[4] collection	44	22
Twice per week[5] collection	59	30

(1) See Table 6.3 for system definition

(2) Based on on-route hours

(3) System-wide average for AGCS (see Table 6.2)

(4) Measured during one-year EPA study

(5) Estimated assuming 50% work force increase required for twice per week collection.

Twice per week productivity = $\frac{2}{1.5}$ x once per week productivity.

Productivity measurements are a helpful tool for evaluating how well a given municipal refuse collection system is working. However, the most important consideration is the economic efficiency of the system.

A basic measurement of the cost efficiency of a given refuse collection system is the weekly cost for serving each home ($/home-week). Using this parameter it is possible to compare systems whose total costs are completely different due to the sizes of the areas they serve. The method of analysis that will be used here is as follows:

1. Determine the average system per crew productivity (P).
2. Determine the average productive (on-route) time worked per day(T).
3. Calculate the average number of homes serviced per day (NH).
   NH = 1/2 PxT (twice per week collection)
   NH = PxT (once per week collection)
4. Determine the total per crew daily costs.
   - o Personnel Cost (PC)
     - wages
     - fringe benefits
     - personnel overhead
   - o Equipment Cost (EC)
     - capital cost
     - debt service
     - maintenance
     - fuel and oil
     - replacement due to down time
     - loss of productivity due to equipment age
5. Calculate the system cost efficiency (CE).
   CE = (PC + EC)/NH

The cost efficiency for the AGCS has been calculatd. Also the cost efficiencies of Systems A and B were calculated. The cost efficiency

of each system will be comparable because the same cost basis was used (see collection cost calculations in Appendix B). The costs are based on the wages and equipment costs of the AGCS.

Labor Rates - Drivers $4.38/hr
Walkers $3.43/hr
Fringe Benefits - 18%
Personnel Overhead - 13%
Collection Vehicle Costs - $19,300/year

Also the average on-route time for the AGCS was applied to all of the systems. It was thus determined how many homes each system could serve working at its own productivity rate for the same number of hours.

The results of the cost efficiency analysis and comparison are shown in Table 6.5. It is estimated that the unit service cost for the AGCS is about $0.74/home-wk. As would be expected both Systems A and B were more cost efficient than the AGCS for once per week service. However, when the System A and B data was adjusted to twice per week collection the AGCS proved to be more cost efficient than System B ($0.89/home-wk) but not as cost efficient as System A ($0.55/home/wk).

Based on the productivity and cost efficiency analysis as well as the field observations made during this study the following conclusions have been formed.

- The performance of the AGCS is comparable to other systems offering the same nominal level of service from a productivity and cost efficiency point of view.
- It is believed that the productivity and cost efficiency of the AGCS can be improved significantly by system changes in the following areas.
  - Personnel Productivity
  - Routing
  - Level of Service

TABLE 6.5

COST EFFICIENCY OF AIKEN AND COMPARISON SYSTEMS

SYSTEM[1]	Labor Costs (per crew)[2]					Equipment Cost ($/day)	Total Crew Cost ($/day)	On-Route[3] Time (hr/day)	No. Homes[4] Served Per Day	Unit Service Cost ($/home-wk)
	No. Drivers	Unit Cost ($/day)	No. Walkers	Unit Cost ($/day)	Total ($/day)					
Aiken	1	45.9	3.2	35.9	161					
System A						74.2	235	5.9	316	0.74
Once per week collection	1	45.9	1	35.9	82					
Twice per week collection	1	45.9	1	35.9	82	74.2	156	5.9	425	0.37
System B						74.2	156	5.9	283	0.55
Once per week collection	1	45.9	1	35.9	82					
Twice per week collection	1	45.9	1	35.9	82	74.2	156	5.9	260	0.60
						74.2	156	5.9	174	0.89

(1) See Table 6.3 for system definition.

(2) See Appendix B for cost estimates.

(3) Average for AGCS. Apply same on-route time to all systems for comparison purposes.

(4) Based on productivities listed in Table 6.4. Since there are 2 pick-ups/wk provided, "No. Homes Served Per Day" is 1/2 x pick-ups/day.

Concepts which can be used to improve the performance of the AGCS will be discussed later in this chapter.

Trash Collection

The trash collection system in Aiken picks up landscape wastes (brush, leaves, grass cuttings, etc.) and miscellaneous bulky rubbish. The system is operated by the City's Streets and Parks Division and collects residential trash as well as wastes from the many City owned landscaped areas (parks, boulevards, etc.)

The equipment used for trash collection in Aiken consists of trucks with detachable trailers (Swacars). The maximum hauling capacity of these trailers is 10,000 lb. Two person crews travel the streets of Aiken and load trash into the trailers by hand (often using pitchforks). Residential landscape wates are generally placed at the curb side. Four crews work specific routes and a fifth is used for miscellaneous collections throughout town.

The Aiken trash collection trucks do not have the capability of dumping the trailers. The normal practice is to exchange the full trailers for empty ones at the landfill. A vehicle with a special hoist is used to dump the full trailers at the landfill. At times this vehicle will tow an empty trailer to a crew on-route and exchange it for a full one.

During the course of this study data was collected by the Aiken trash crews (similar to that collected by the garbage crews). Table 6.6 shows a productivity analysis of the trash collection crews which was done using this data. During the study period it was found that trash crews were serving between 29 and 59 homes per on-route crew-hour with the system-wide average being about 43.

The subject of trash collection system cost reduction will be addressed later in this chapter.

Commercial Collection

The City of Aiken provides commercial refuse collection service within the City limits. The commercial locations have one or more containers which are emptied by one of three City of Aiken front loading collection vehicles. Approximately 415 of these containers

TABLE 6.6

AIKEN TRASH COLLECTION CREW PRODUCTIVITY

Crew[1]	Average Time (hr/wk)[2] Productive[3]	Non-productive[4]	Total[5]	No. Homes[6] Served	Productivity[7] (homes served/crew-hr)
1	30.0	7.0	37	1340	45
2	25.0	7.1	32	1475	59
3	29.5	7.1	37	1245	42
4	32.0	7.2	39	940	29

System Average: 5000 homes/117 crew-hr = 43 homes served/crew-hr.

(1) Crew numbers used by City of Aiken Streets and Parks Division.

(2) From data taken by collection crews during April and May, 1980.

(3) On-route collecting time.

(4) Time spent on breaks, travel to/from route and travel to/from landfill.

(5) Total from time crew leaves motorpool until crew returns to motorpool.

(6) Based on information provided by City of Aiken Personnel.

(7) Based on on-route time. Does not account for help provided by fifth crew.

are located at the commercial locations within the City. The commercial locations are serviced one or more times per week depending upon the amount and type of refuse being produced.

City of Aiken personnel have requested aid in determining commercial collection costs. They seek this to help them examine their commercial collection fee structure. This topic will be addressed later in this chapter.

METHODS FOR INCREASING SOLID WASTE COLLECTION SYSTEM PERFORMANCE

The objective of this section is to investigate methods which can be used to increase the productivity and cost efficiency of refuse collection in Aiken. Garbage and trash collection will be addressed separately.

Garbage Collection System

During the course of this study it has been determined that there is potential for improving garbage collection system performance in the following areas:

- o Personnel Productivity
- o Routing
- o Level of Service

Personnel Productivity

One basic approach to reducing collection system costs is to increase per crew productivity. If the productivity of the individual crews can be increased enough it will be possible to perform city wide collections with fewer crews and, thus, at a lower total cost. Based on on-route observation of AGCS collection workers it is believed that there is definitely room for improvement in the area of individual personnel productivity.

Consider the example of comparison systems A and B that were discussed earlier in this chapter. The basic operating conditions for the two systems were the same except for incentive system (see Table 6.3). System A was operated on a task incentive program while

System B was operated with crews working a standard 8-hour day. During the EPA study of the two systems it was found that System A was about 62% more productive than System B (i.e. the System A crews made an average of about 62% more pick-ups per hour). It is highly probable that there were other factors that contributed to the difference in productivity of the two systems (such as housing density). However, it is doubtless that the task incentive program used with System A was a major factor in making it more productive than System B.

With a task incentive program collection workers are given a specific group of tasks which must be accomplished each day (i.e., collection, travel to landfill, vehicle wash, etc.). The workers are allowed to leave work when these tasks have been satisfactorly completed but are paid for a full 8-hour day. The individual worker is given the incentive to work efficiently and productively so he/she can leave work early while still being paid for 8 hours. Task incentive systems have been used with many refuse collection systems and have helped to improve system productivity in most cases.

An important concern with a refuse collection task system is maintaining good service quality. It is undesirable to have collection workers missing pick-ups, spilling garbage, etc., in an effort to finish their tasks quicker. One approach to this problem is to have the entire crew that makes a mistake on-route return to correct it. This gives the workers the incentive to do the job properly the first time.

There are two ways in which an increase in crew productivity could be used to obtain a system cost savings for the AGCS. If the per crew productivity could be increased by an average of 60% (as in the case of Systems A and B) it would be possible to service the entire town with three crews instead of four and still have the collection personnel working an average of one hour less per day (a necessary portion of the task incentive concept). Based on current wage rates this would mean an annual operational cost savings of about $59,000 (see Appendix B for cost estimates). However, though

it is doubtless that a task incentive program would improve the productivity of the AGCS crews, it may not be reasonable to expect an increase as large as 60%. It is more practical for larger systems (with many more crews than the AGCS) to translate smaller productivity increases into crew reductions.

There is another way in which an improvement in productivity might be more practically applied to the AGCS. If the per crew-member productivity could be increased by about 50% by instituting a task incentive program it would be possible to use an average of one less person on each crew (average of 3.2 persons per crew) and have the crews working one hour per day less than they are now. This would require a productivity of about 40 pick-ups per crew-person per hour (128 pick-ups/crew-hr). This is about 17% less than the twice per week collection per crew-person productivity estimated for System A (see Table 6.4). A reduction of four walkers would mean a system savings of about $37,000 (see Appendix B).

It may be that the 50% increase in personnel productivity discussed in the previous paragraph is not practically attainable in Aiken due to the physical characteristics of the town. However it might still be possible to use an improved system productivity (due to a task incentive program) to create a system cost reduction. It might be that a system using a combination of 4-person crews and 3-person crews would be logical for Aiken. An incremental approach to labor force reduction might be a good way to increase the system's performance.

1. Institute a task incentive program with the existing AGCS crews. Allow a period of time for the collection workers to get used to the system and monitor how long collections are taking.
2. If the incentive program is effective at reducing the total daily time that the AGCS crews are working make an incremental reduction in the labor force (1 or 2 walkers). A route adjustment might be necessary to balance the task times for the crews. Allow an acclimation period and continue to monitor the daily crew times.

3. Continue making incremental reductions in the labor force (as described in Step 2) until a desirable labor force level has been achieved. At this point the crews should be working less than 8 hours per day (6.5-7) but not by an excessive amount (a 4 hour average task time would indicate an under utilized task system).

At this time it is not possible to estimate how many incremental labor force reductions could be made or the associated cost savings.

During on-route observation of the AGCS crews it was noted that the walkers used tote barrels. These barrels are fairly large (40 to 50 gallons) and are quite heavy when full. The walkers were, in many cases, having difficulty in carrying these barrels. If tote barrels with wheels were used (similar to a barrel mounted on a light-weight hand truck) it might improve the speed with which the walkers work and reduce the physical effort required. This could result in an improvement in productivity and a reduction of worker injuries. This type of tote barrel is available commercially.

Routing

It is believed that the performance of the AGCS can be enhanced by an improved routing system. This statement is based on the following facts.

- The routes are not well balanced and the AGCS crews are spending unequal amounts of time collecting (previously discussed).
- The macro routes for each crew (area of route coverage) are not contiguous.
- The micro routes (specific paths of travel) are not systematic and the crews do a considerable amount of backtracking during a day's collection.

Table 6.7 shows the average number of miles that each crew was traveling on-route during the data collection program. Also shown are the total linear miles of street within each route. It can be seen that, in most cases, the AGCS crews follow paths that result in a considerable amount of backtracking. This statement has been confirmed during crew observations. It is likely that an improved

TABLE 6.7

ON-ROUTE MILES TRAVELED BY GARBAGE COLLECTION CREWS

Crew	Route[1]	Average Miles[2] Traveled On-route	Miles of Street[3] Within Route	Duplication[4] Factor
HS-21	M-T	29	17	1.71
	T-F	28	15	1.20
HS-22	M-T	27	16	1.69
	T-F	19	11	1.73
HS-23	M-T	25	25	1.00
	T-F	20	21	0.95
HS-25	M-T	32	20	1.60
	T-F	15	8	1.88
			Average =	1.5

(1) M-T = Monday-Thursday route; T-F = Tuesday-Friday route

(2) From data collection forms completed by AGCS drivers

(3) Total linear miles of street within route

(4) Miles traveled/total miles of street. In some cases streets within route are not traveled due to a lack of pick-up locations.

routing scheme for the AGCS would improve system productivity and reduce equipment operation costs.

During the course of this study a new macro routing plan was developed for the AGCS. Information concerning the new routes is shown on Table 6.8 and individual route maps are located in Appendix C. The new macro routes are an improvement over the present routes based on the following facts:

- o The new routes (where possible) are more compact
- o The new routes are contiguous
- o The new routes have been designed to provide a better balance of on-route time among the crews (see Table 6.8).

The heuristic method of micro-routing was used to plan the collection vehicle paths for each of the routes (indicated by arrows on the maps in Appendix C). These paths allow for collection of all the residences on each route with a one pass methodology. Dead travel and backtracking were minimized. The micro-routes are all continuous and show no breaks for off-route lunch or landfill trips. When the collection vehicle leaves the route collection should be resumed at the point where it was discontinued. It is believed that these micro routes are an improvement over the ones presently used by the AGCS.

Level of Service

It may be that the only way to obtain drastic cost savings with the AGCS is to reduce the level of service. There are two changes in the basic level of service of the AGCS that could be used to reduce system costs.

- o Change from twice per week collection to once per week collection.
- o Change from backyard refuse placement to curb side placement.

The reduction in level of service from twice per week to once per week collection has a very good potential for providing a cost reduction with the AGCS. It is a general rule (which works well in

TABLE 6.8

RESTRUCTURED GARBAGE COLLECTION ROUTES

Route[1]	No Homes	Estimated Productivity[2] (pick-ups/crew-hr)	Estimated Collection Time Required (hr/day on-route)
A	747	122	6.1
B	403	66	6.1
C	493	85	5.8
D	635	102	6.2
E	713	119	6.0
F	644	106	6.1
G	718	118	6.1
H	724	125	5.8

(1) See Appendix C for route maps

(2) Based on per crew performance during data collection period

most cases) that a labor force reduction of 33% can be made if the switch is made from twice per week to once per week collection. Since the AGCS uses four crews this would probably mean an elimination of one crew and a resulting cost savings of $59,000/yr.

One problem which could occur with a change in collection frequency is that a health hazard might be created. Standing household refuse provides a good environment for the breeding of flies and other disease spreading pests. The potential for this problem is partially dependent upon the climate. In some hot and humid places household refuse is disposed of more than once per week to prevent a fly problem rather than to provide more convenient service. Considering the climate of Aiken it is likely that once per week collection would have public health or nuisance impacts; at least during summer months. Based on the possible impacts it is concluded that changing to once per week collection would not be an acceptable alternative for the City of Aiken.

A change from backyard to curb side collection has good potential for reducing AGCS costs. This one move would probably have a greater impact on costs than any other system change that could be made.

A system comparison will be used to illustrate how a change to curb side collection and institution of a task incentive program could impact the productivity and cost efficiency of the AGCS. The operating parameters for the systems that will be compared are given in Table 6.9. The C, D and E systems were subjects of the EPA study that has been previously discussed. The Birmingham system was studied during a recent EPA Technical Assistance Project. The major operating differences between the systems are:

- o Crew size
- o Incentive system
- o Refuse container placement

The productivities for the AGCS and the four comparison systems are summarized in Table 6.10. It can be seen that the AGCS is more

TABLE 6.9

OPERATING PARAMETERS FOR AIKEN AND CURBSIDE SYSTEMS

System[1]	Operating Agency	Crew[2] Size	Incentive System	Equipment[3] Type	Collection Frequency	Collection[4] Methodology	Storage[5] Container	Container[6] Placement
Aiken	Public	4-5	None	Rear Loader	2/wk	Tote barrel Both Sides	B&C	Backyard
C	Public	1	Task	Side Loader	2/wk	One side	B&C	C/A
D	Public	2	Task	Side Loader	2/wk	One side	B&C	C/A
E	Public	3	Task	Read Loader	2/wk	Both sides	B&C	C/A
Birmingham	Public	4	Task	Read Loader	2/wk	Both sides	B&C	C/A

(1) Data for Systems C, D and E taken from "Residential Collection Systems; Volume 1", EPA/530/SW-97c.1, U.S. EPA, 1975. Data for Birmingham developed during EPA Technical Assistance Project

(2) Includes drivers and walkers

(3) Packer capacity varies

(4) One side = one side of street collected per pass (two pass system)
Both side = both sides of street collected on one pass (one pass system)
Tote barrel = tote barrel used, both sides of street collected on one pass.

(5) B&C = Bags and cans

(6) C/A = curb side and alley

TABLE 6.10

PRODUCTIVITY OF AIKEN AND CURBSIDE COLLECTION SYSTEMS

System[1]	Productivity		
	Pick-ups made:		
	per crew-hr[2]	per crewperson-hr[2]	Crew Size
Aiken[3]	107	26	4-5
System C[4]	84	84	1
System D[4]	138	67	2
System E[4]	201	67	3
Birmingham[5]	311	78	4

(1) See Table 6.9 for system definition

(2) Based on on-route hours

(3) System-wide average of AGCS (see Table 6.2)

(4) Measured during one-year EPA study.

(5) Based on analysis done as part of EPA Technical Assistance Project

productive on a per crew basis than System C (one person crew). However, it is not as productive as System D (two person crew) or the systems with larger crews. The per crewperson productivities listed in Table 6.10 show that the productivities of the curbside task systems range from a multiple of 2.6 to 3.2 times the productivity of the AGCS.

A cost efficiency comparison between the AGCS and the curbside/task systems is shown in Table 6.11. As with the previous cost efficiency analysis, the unit service costs for all the systems are comparable because the same basic costs (labor and equipment) were used to develop the daily crew operating costs. As would be expected (due to the level of service) all of the curbside/task collection systems are more cost efficient than the AGCS. The unit service cost of the curbside/task systems range from 34% to 65% of the AGCS unit service cost. Also the cost efficiency of the curbside/task system increase as the crew size increases.

It has been shown that curbside/task systems which were compared with the AGCS are much more productive and cost efficient. It cannot be exactly determined what portion of the increased performance is due to curbside collection and what portion is due to the task incentive program. However, during the EPA sponsored research it has been found that, when considering productivity, the magnitude of the effect of container placement is more than twice the effect of incentive system. It was also found that the magnitude of the effect of the container placement is more than fifty times the effect of incentive system when considering cost efficiency. When comparing the AGCS with the curbside/task systems it is safe to say that the increase in productivity is primarily due to container placement and the increase in cost efficiency is almost totally due to container placement.

If a task incentive program were to be instituted with the AGCS and the change was made from backyard to curbside placement a considerable system cost savings could be incurred. In fact if two four-person crews spend 4.9 hours per day on-route (one hour per day less than the crews are currently spending on-route) it would be possible to service the entire city with twice per week collection. The required productivity would be 255 pick-ups/crew-hr which is about

TABLE 6.11

COST EFFICIENCY FOR AIKEN AND CURBSIDE SYSTEMS

System[1]	LABOR COST (per crew)[2] No. Drivers	Unit Cost ($/day)	No. Walkers	Unit Cost ($/day)	Total ($/day)	Equipment[2] Cost ($/day)	Total[2] Crew Cost ($/day)	On-Route[3] Time (hr/day)	No. Homes[4] Served Per day	Cost Per Home Served ($/wk)
Aiken	1	45.9	3.2	35.9	161	74	235	5.9	316	0.74
C	1	45.9	0	35.9	46	74	120	5.9	248	0.48
D	1	45.9	1	35.9	82	74	156	5.9	407	0.38
E	1	45.9	2	35.9	118	74	192	5.9	593	0.32
Birmingham	1	45.9	3	35.9	154	74	228	5.9	918	0.25

(1) See Table 6.9 for sysem definition

(2) See Appendix B for cost estimates

(3) Apply AGCS on-route time to all systems for comparison purposes

(4) Based on productivities shown in Table 6.10

18% less than the Birmingham system previously discussed (4-persons crews; curbside/task system). It is believed that this productivity target is reasonable for the AGCS if the appropriate system changes were made. The resulting savings would equal about one-half of the AGCS system costs or approximately $118,000/yr based on current labor rates and equipment costs.

Summary of Garbage Collection Cost Saving Options

A number of concepts which could be applied to the AGCS have been defined.

- o Improved Personnel Productivity
- o Improved Routing Plan
- o Change in Level of Service

It is believed that AGCS costs can be reduced in all three of these areas. However the most significant cost savings would be incurred by changing the level of service from backyard to curb side refuse placement. It is possible to reduce labor and equipment requirements by one-half if curb side refuse placement were used and a task incentive program were instituted.

Trash Collection

The method of trash collection which is being used in Aiken has been previously described. During on-route observation done over the course of this study it has been noted that a significant amount of the refuse collected by the trash crews consists of relatively small piles of landscape wastes placed at the curbside.

It is believed that the method of trash pick-up used is inherently inefficient for the collection of small piles of loose yard wastes. The workers must gather the loose refuse by hand or pitchfork and lift it to approximately head level to load it into the trash trailers. This type of loading is much less efficient than the motion required to load refuse into a conventional rear load packer vehicle. It makes much more sense to require that small piles of loose cuttings be containerized by the residents (bag or can) and then collect them during garbage collection.

There are piles of limbs, etc. which are collected by the trash crews and are too large and bulky to be practically loaded into a packer vehicle. This type of pick-up could be made from residents on an as-requested basis using truck and trailer equipment.

It is fair to estimate that a significant portion of the trash collection system work force and equipment could be eliminated if the residents of Aiken were required to containerize small quantities of loose landscape wastes for collection along with household garbage. This would apply to wastes such as grass clippings, etc. Branches which are difficult to containerize could be bound in bundles limited to 4 ft in length and also collected along with grabage.

COMMERCIAL SERVICE COST ESTIMATES

City of Aiken personnel have specifically requested aid in determining commercial service costs (collection and disposal). The objective is to develop a systematic and equitable method for setting commercial service fees.

The cost for commercial service with front load vehicles and containers can be broken into three components.

- o Collection cost
- o Disposal cost
- o Container cost

Collection Costs

To determine the average per container collection cost two pieces of information are required.

- o Total daily cost per crew (TDCC)
- o Average number of containers emptied per day (NC)

These items are used to calculate the per container collection cost (CC).

$$CC = TDCC/NC$$

Examples of cost estimates of CC for residential garbage collection have been previously shown based on the item cost estimates presented in Appendix B (in fact the calculation of CC is very similar to calculation of the unit service costs, $/home-served, presented earlier in this

chapter). At a given commercial establishment the CC should be considered constant for each container but the total collection cost for the establishment will vary according to the number of containers at the location.

Disposal Cost

The first step in determining the disposal cost for commercial service is to calculate the unit landfill cost (ULC). This calculation requires two pieces of information.

- o The total annual cost for operation of the landfill (ALC)
- o The total quantity of refuse (cu yd) disposed of at the landfill annually (AYD).

An estimate of the annual landfill costs (ALC) was presented in Chapter 3, however, it is likely that the City of Aiken accountants can improve upon this estimate. The quantity of disposed refuse (AYD) should be in cubic yards at an "in-container" density. The unit landfill cost is then calculated:

$$ULC = ALC/AYD$$

The ULC cost should be constant for all commercial establishments but the total disposal cost will vary from location to location depending upon number of containers (NC), container volume (V) and number of collections per week (NW).

Container Costs

Another part of the total commercial service cost is the cost for the front load containers. This can be estimated knowing the front load container capital cost (FLCC) and the usable life of the container in years (CL). The annual container cost (AFLCC) is:

$$AFLCC = FLCC \times \frac{R\ (1+R)^{CL}}{(1+R)^{CL} - 1}$$

where R is the minimum acceptable rate of return (expressed as a decimal fraction). The weekly front load container cost (WFLCC) is then:

$$WFLCC = AFLCC/52$$

The WFLCC will vary depending upon the size of the container.

Total Commercial Service Costs

Once the collection, disposal and container costs have been determined it is possible to calculate the total commercial service cost (TCSC).

$$TCSC = (NW \times NC \times CC) + (NW \times NC \times V \times ULC) + (NC \times WFLCC)$$

The variables in this equation are numbers of pick-ups per week (NW), number of containers (NC), volume of refuse per container (V) and weekly front load container cost (WFLCC). The constants in the equation are collection cost (CC) and unit landfill cost (ULC). The equation should be evaluated for all applicable combinations of the variables. The results can then be entered into commercial service cost schedules (an example is shown in Figure 6.2). One commercial service cost schedule should be generated for each applicable container size. These schedules can then be used as a basis for setting commercial service fees.

Example

Perhaps the easiest way to illustrate the calculation of commercial service costs is through an example. The unit costs that will be used are reasonable but are not necessarily correct for Aiken. The example is for illustrative purposes only.

EXAMPLE: Calculate the weekly commercial service cost for an establishment having four 6-cu yd containers which are picked-up three times per week.

ASSUME:

- Daily collection labor cost = $82/day (one driver, one helper)
- Annual collection vehicle cost = $27,000/yr
- Crew productivity = 140 containers/crew-day
- Annual landfill cost = $114,000/yr
- Annual quantity of refuse disposed of at landfill = 120,000 cu yd/yr (at 200 lb/cu yd)
- Capital cost for 6-cu yd front load containers = $500 each

EXAMPLE OF COMMERCIAL SERVICE COST SCHEDULE

CONTAINER VOLUME = _____ CU. YD.

NUMBER OF PICK-UPS PER WEEK

NUMBER OF CONTAINERS	1	2	3	4	5	6
1						
2						
3						
4			*			
5						

COLLECTION COST ($/MONTH)

- Average life of front load containers = 10 yr each
- Minimum acceptable rate of return = 10% per year
- Assume containers average 70% full

Collection Cost

Total daily crew cost = 82 + (27,000/52x5)

= $186/day

Per container collection cost (CC)

= 186/140 = $1.33/container (per pick-up)

Disposal Cost

Unit landfill cost (ULC) = ALC/AYD

= 114,000/120,000 = $0.95/cu yd (at 200 lb/cu yd)

Container Cost

Annual front load container cost (AFLCC)

$$= FLCC \times \frac{R(1+R)^{CL}}{(1+R)^{CL}-1}$$

$$= 500 \times \frac{0.10\ (1+0.10)^{10}}{(1+0.10)^{10}-1} = \$81.4/yr \text{ per container}$$

Weekly front load container cost (WFLCC)

= 81.4/52 = $1.57/wk per container

Total Commercial Service Cost

TCSC = (NWxNCxCC) + (NWxNCxVxULC) + (NCxWFLCC)

= (3x4x1.33) + (3x4x0.7x6x0.95) + (4x1.57)

= $70.12/wk

Monthly Commercial Service Cost

= 70.12 x (52/12) = $303/month

If the commercial service cost schedule shown in Figure 6.2 were for 6 cu yd containers then $303 would be entered in the box with the asterisk (*).

APPENDIX A

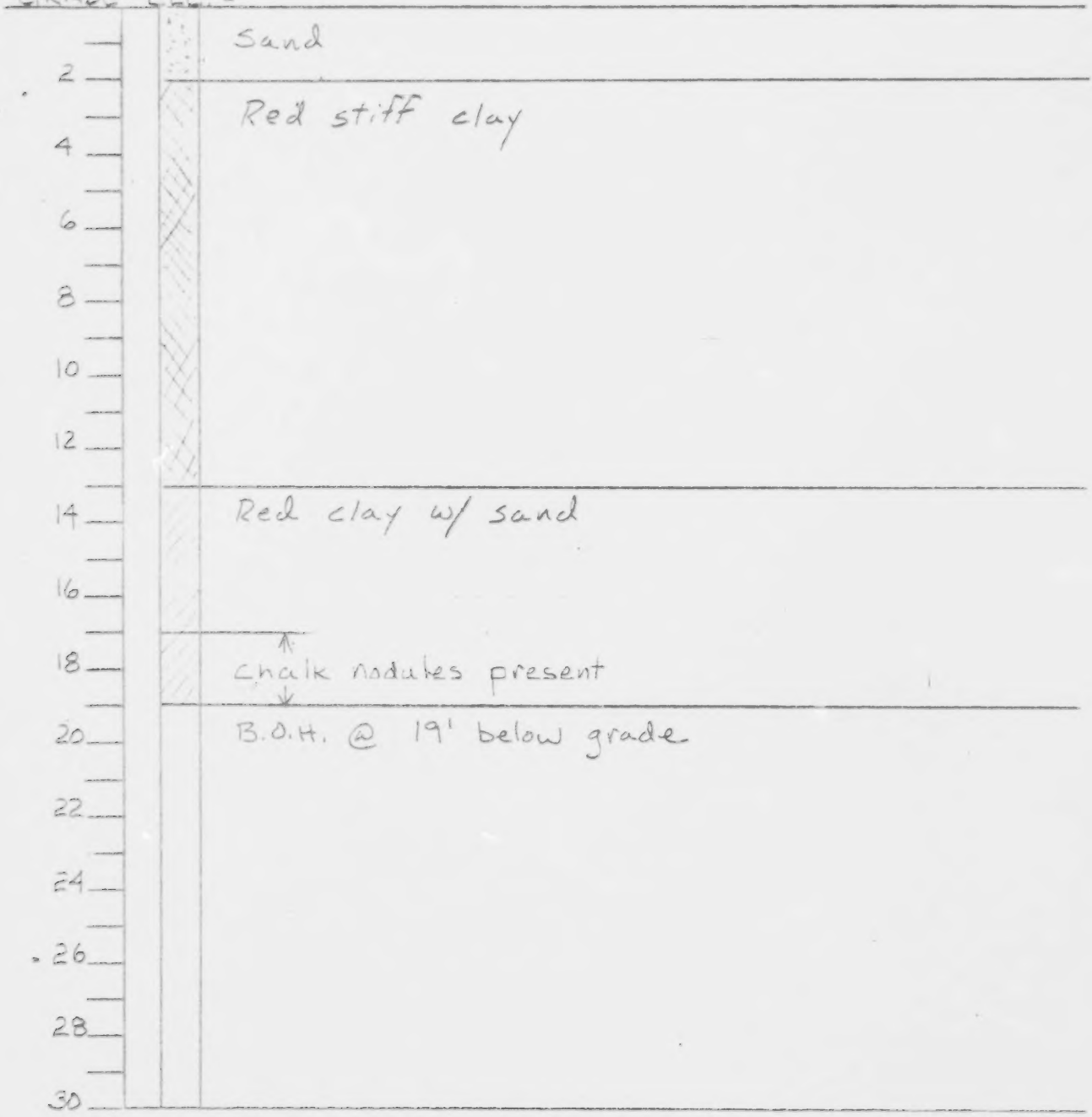
TEST BORING LOGS

TEST BORING LOG

BORING # TB1

DATE 4/10/80
NAME REM
ES JOB # 3600
LOCATION AIKEN SC.

GRADE ELE. =



ENGINEERING-SCIENCE, INC.
EXECUTIVE PARK SOUTH, N.E., SUITE 550
ATLANTA, GEORGIA 30329
AREA 404 325-0770

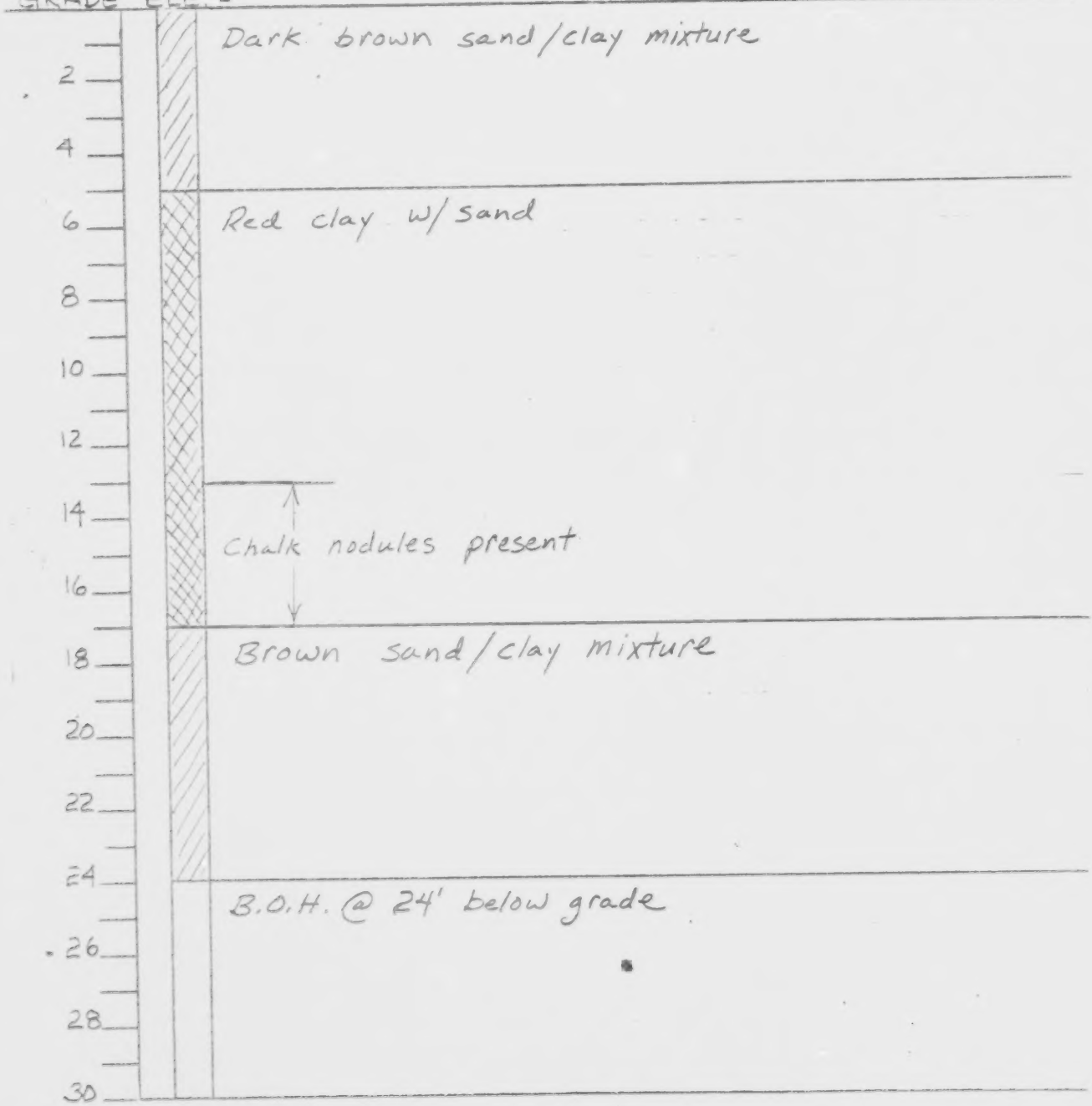
PROJECT TECH ASST AIKEN JOB NO 3600
DETAIL TB1a
DATE 4/11/80
BY REM
SHT 1
OF 13

TEST BORING LOG

BORING # TB2

DATE 4/10/80
NAME REM
ES JOB # 3600
LOCATION AIKEN S.C.

GRADE ELE. =

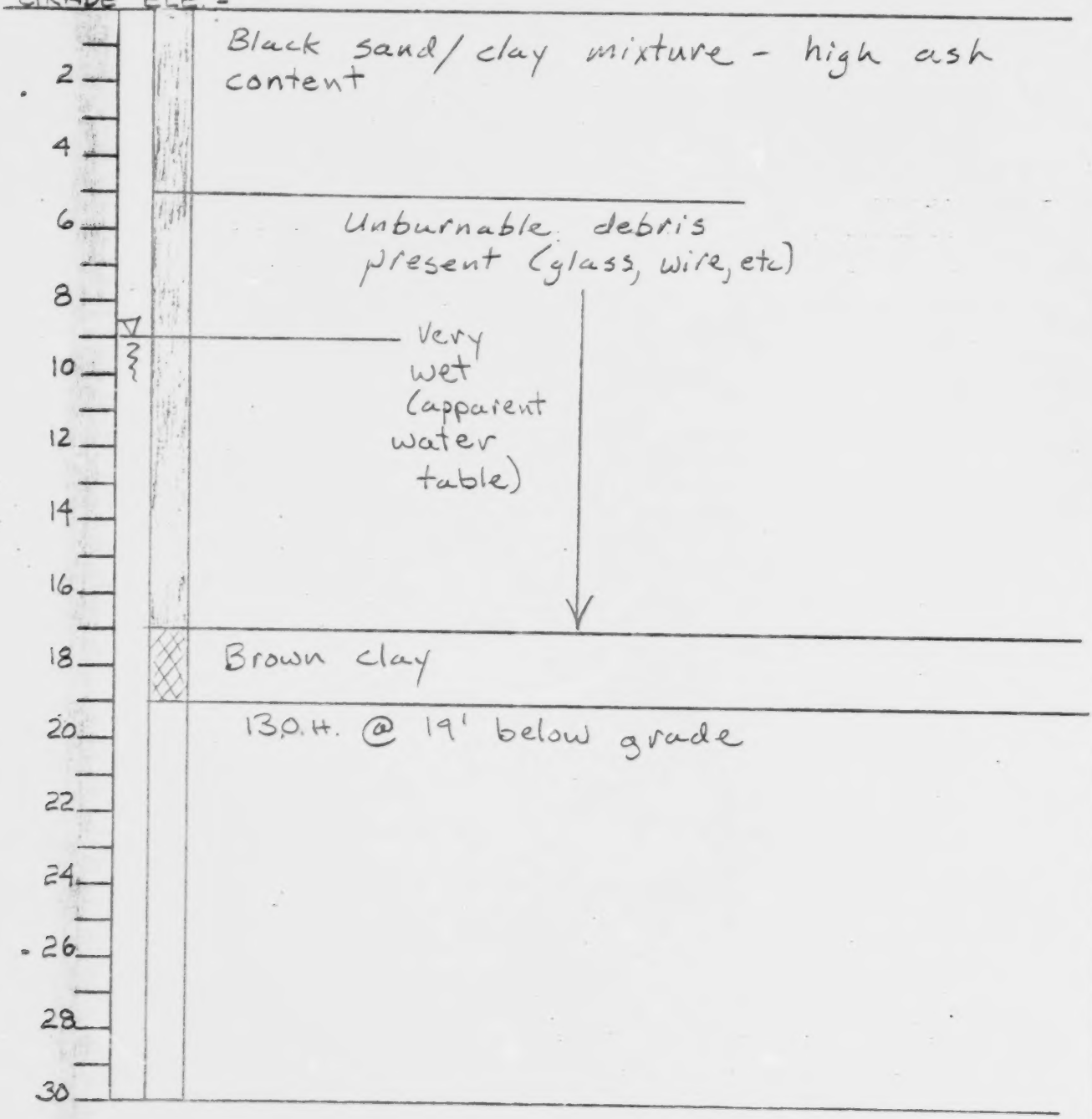


TEST BORING LOG

BORING # TB3

DATE 4/10/80
NAME REM
ES JOB# 3600
LOCATION AIKEN S.C.

GRADE ELE =



TEST BORING LOG

BORING # TB4

DATE 4/10/80
NAME REM
ES JOB# 3600
LOCATION AIKEN S.C.

GRADE ELE. =

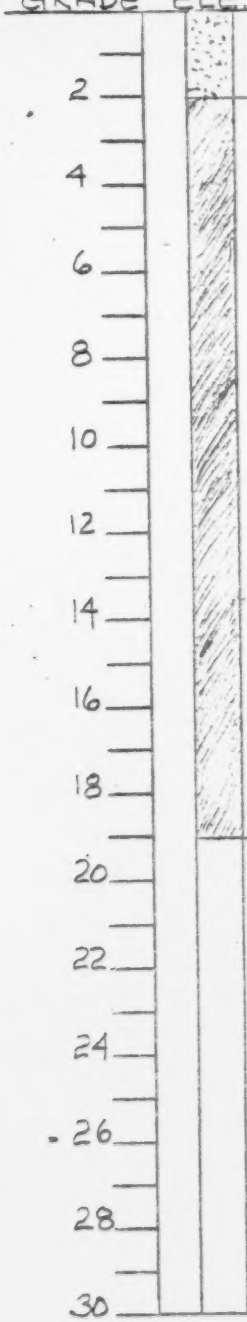
0	Top soil
2	Black clay/sand mixture - high ash content - unburnable debris present (glass, wire, etc.)
4	
6	Tan clay / sand mixture
8	
10	Dark brown clay w/ sand
12	Red clay w/ small amount of sand
14	Red clay/sand mixture w/ chalk nodules
16	
18	B.O.H. @ 19' below grade
20	
22	
24	
26	
28	
30	

TEST BORING LOG

BORING # TB5

DATE 4/10/80
NAME REM
ES JOB # 3600
LOCATION AIKEN S.C.

GRADE ELE. =



Red wet sand

Black to dark grey clay/sand mixture - much unburned burnable debris present (paper, rags, etc.) - decayed organic odor present

B.O.H. @ 19' below grade

TEST BORING LOG

BORING # TB6

DATE 4/10/80
NAME REM
ES JOB # 3600
LOCATION AIKEN S.C.

GRADE ELE. =

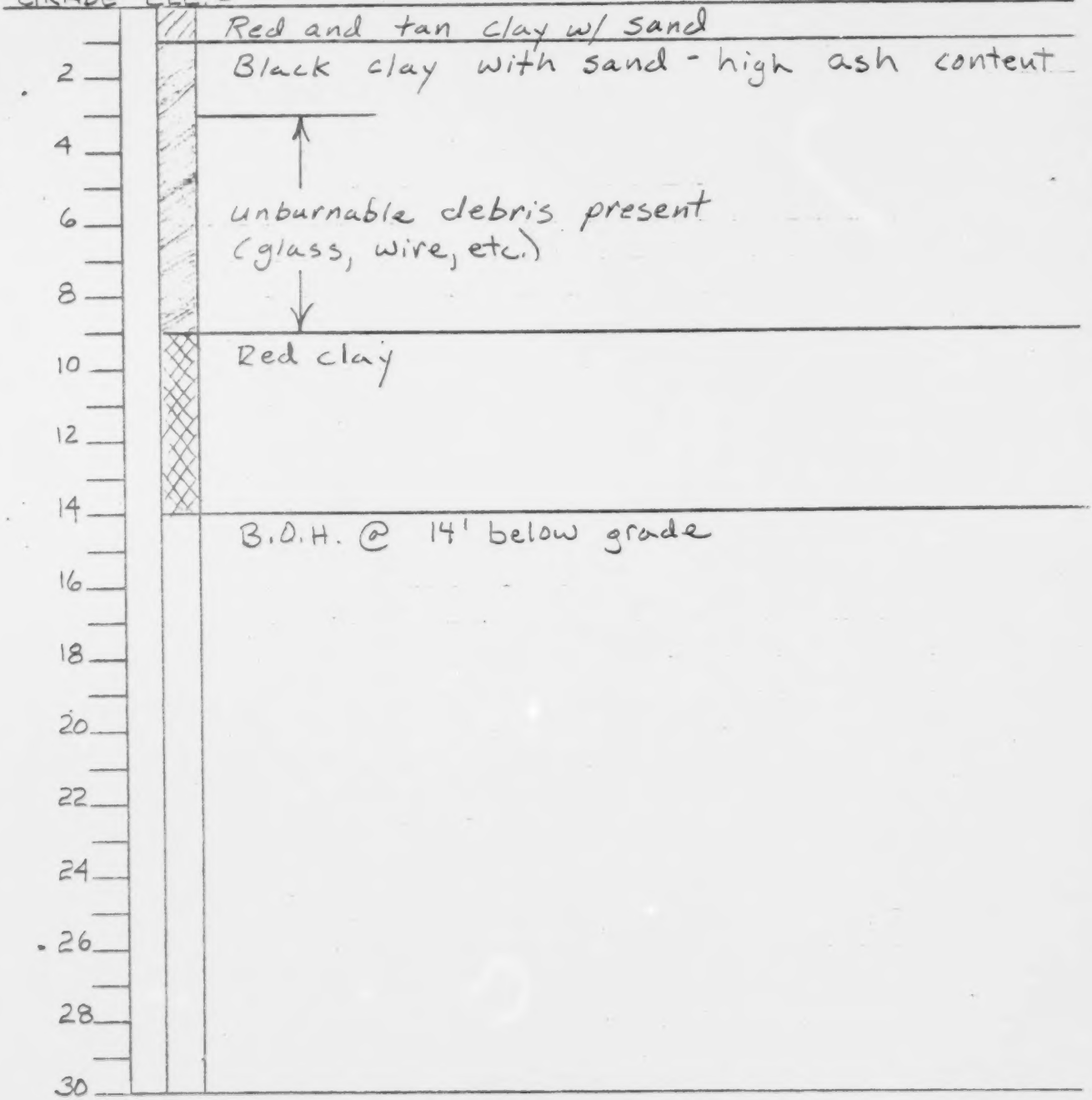
0	Red sand w/ sand/clay nodules
2	Black muck w/ debris - significant decayed organic odor present
4	Yellow sand w/ small amount of clay
6	Brown sand
8	Grey sand/clay mixture w/ debris - decayed organic odor present
10	
12	
14	
16	
18	
20	B.O.H. @ 19' below grade
22	
24	
26	
28	
30	

TEST BORING LOG

BORING # TB7

DATE 4/10/80
NAME REM
ES JOB# 3600
LOCATION AIKEN S.C.

GRADE ELE. =

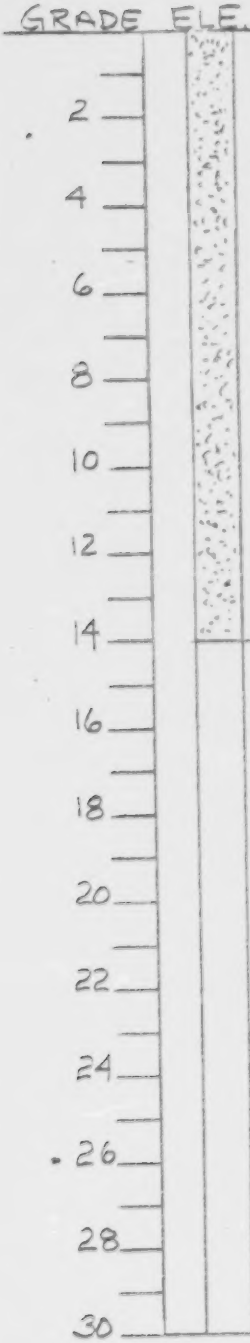


TEST BORING LOG

BORING # TB8

DATE 4/10/80
NAME REM
ES JOB# 3600
LOCATION AIKEN S.C.

GRADE ELE. =



Red sand w/ small amount of silt

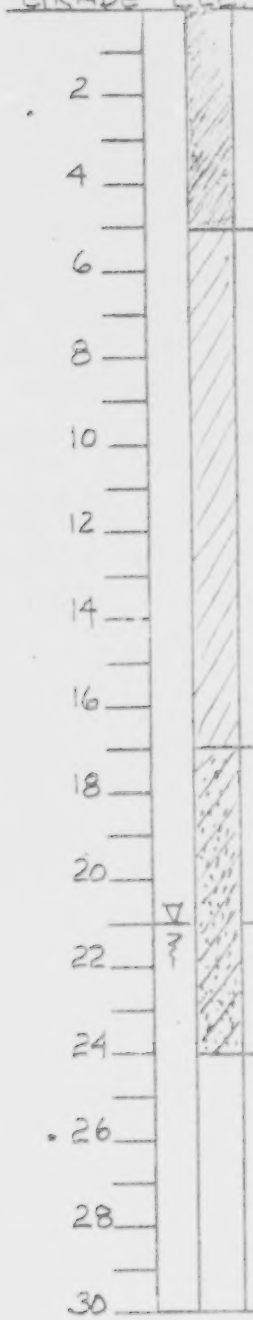
B.O.H. @ 14' below grade

TEST BORING LOG

BORING # TB9

DATE 4/10/80
NAME REM
ES JOB # 3600
LOCATION AIKEN S.C.

GRADE ELE. =



Black clay - high ash content - much debris present - slight decayed organic odor

Dark grey sand/clay mixture - decayed organic odor present

Red sand w/ clay

▽ ? very wet (apparent water table)

B.a.H. @ 24' below grade

TEST BORING LOG

BORING # TB10

DATE 4/10/80
NAME REM
ES JOB# 3600
LOCATION AIKEN S.C.

GRADE ELE =

0	Black clay w/ sand - high ash content - debris present
2	Red clay w/ sand - no debris noted
4	
6	
8	
10	Same w/ increased sand content
12	Red sand w/ small amount of silt
14	
16	Red sand/clay mixture
18	
20	
22	Red clay w/ sand - fairly stiff
24	B.O.H. @ 24' below grade
26	
28	
30	

TEST BORING LOG

BORING # TB11

DATE 4/10/80
NAME REM
ES JOB# 3600
LOCATION AIKEN SC

GRADE ELE. =

Red sand

Dark grey muck w/ much debris - obvious decayed organic odor

▽ Very wet (apparent water table)

?

Red sand/clay mixture

B.O.H. @ 19' below grade

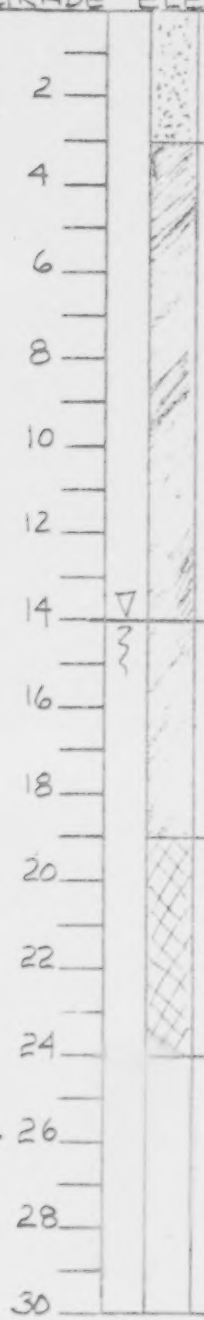
ENGINEERING-SCIENCE, INC. EXECUTIVE PARK SOUTH N.E. SUITE 580 ATLANTA, GEORGIA 30329 AREA 404 [illegible]	PROJECT TECH AST AIKEN JOB NO 3680 DETAIL TB11	DATE 4/11/80 BY REM	SHT 11 OF 13

TEST BORING LOG

BORING # TB12

DATE 4/10/80
NAME REM
ES JOB# 3600
LOCATION AIKEN S.C.

GRADE ELE. =



Brown sand

Black to dark grey muck w/ unburned burnable refuse (paper, rags, etc.) - significant decayed organic odor

▽ Very wet (apparent water table)

Brown clay

B.O.H. @ 24' below grade

TEST BORING LOG

BORING # TB13

DATE 4/10/80
NAME REM
ES JOB# 3600
LOCATION AIKEN S.C.

GRADE ELE. =

0 – 2	Brown sand
2 – 16	Dark colored sand w/ some clay - unburned burnable debris present (paper, rags, etc) - decayed organic odor
16 – 24	Grey muck - very wet - strong decayed organic odor - no visable debris
24 – 30	Red clay w/ some sand - decayed organic odor present in this strata
30	B.O.H @ 29' below grade

ENGINEERING-SCIENCE, INC.
TECUTIVE PARK SOUTH N.E. SUITE 590
ATLANTA, GEORGIA 30329
AREA 404 325-0770

PROJECT TECH ASST AIKEN JOB NO 3600
DETAIL TB13
DATE 4/11/80
BY REM
SHT 13
OF 13

APPENDIX B
COST ESTIMATE CALCULATIONS

SOLID WASTE TRANSFER COSTS

Estimate municipal solid waste production rate based on rates measured for similar communities.

Household	-	2.7 lb/person-day	(7-day basis)
Landscape	-	0.8 lb/person-day	
Commercial	-	0.8 lb/person-day	
Total	-	4.3 lb/person-day	

Assume population is 15,000

$$15{,}000 \times \frac{4.3}{2000} = 32 \text{ TPD} = 12{,}000 \text{ ton/yr}$$

The following equation has been developed based on capital and operating costs of existing transfer facilities (Reference: P.A. Vesilind, et.al; Solid Wastes Management, November, 1977):

$$M = (3.44 \times 10^{-6})\, N^3 + (8.6 \times 10^{-4})\, N^2 - (7.29 \times 10^{-2})N + 2.73$$

where: M = transfer facility cost ($/ton)

N = transfer station capacity (1000 ton/year)

Evaluation of the equation at 12,000 ton/year yields:

$2.0/ton (1977 $)

Increase cost at 12%/year to project 1980 cost.

$2.0 \times 1.12^3 = \$2.8$/ton (1980 $)

Estimate packer haul costs based on 1976 EPA National Average costs (assumes only one person per vehicle).

Packer vehicle - $0.32/ton-mile (1976 $)

$0.32 \times 1.12^4 = \$0.50$/ton-mile (1980 $)

Note: This figure is consistent with other estimates of current packer haul costs done by Engineering-Science, Inc. and CSI Resource Systems, Inc.

Estimate transfer vehicle haul costs assuming that all Aiken refuse can be hauled using one (1) 40-ton truck tractor with one (1) 20-cu yd dump trailer.

From Means Building Construction Cost Data (1980) costs are:

Tractor - $185.80/day

Trailer - $73.00/day

(Note: Costs include capital, operation and maintenance)

Total daily equipment cost = $258.80/day

Total annual equipment cost = $67,000/yr

Assume one (1) driver paid at $4.50/hr with 18% fringe benefits and 13% personnel overhead

Annual labor cost = $4.50 \times 8 \times 5 \times 52 \times (1 + 0.13 + 0.18)$

= $12,000/yr

Total haul cost = 67,000 + 12,000 = $79,000/yr

Unit haul cost = 79,000/12,000 = $6.6/ton

Estimated transfer operation costs for Aiken:

2.8 + 6.6 = $9.4/ton

Estimated haul with packer vehicle for Aiken ($/ton):

$0.50 \times D$

where: D = distance to disposal facility (miles).

LANDFILL COSTS

Land

Assume $3000/acre land value.

Assume 2 acre/year land use.

Annual land cost = $6000/year

Equipment

Based on information from equipment vendor; current cost for loader similar to one used at Aiken landfill is about $136,000. Assume equipment life is 5 years. Assume minimum acceptable rate of return is 10%.

$$\text{Annual cost} = \frac{136{,}000 \times 0.10\ (1+0.10)^5}{(1+0.10)^5-1} = \$36{,}000/\text{yr.}$$

Assume 1 pick-up at $7000 with usable life of 3 years.

$$\text{Annual cost} = \frac{7000 \times 0.10\ (1+0.10)^3}{(1+0.10)^3-1} = \$2{,}800$$

Total annual equipment capital cost = 36,000 + 2,800 = $39,000/year

Direct Operating Costs

1972 EPA estimate of direct operating costs for heavy landfill equipment was $3.00/hr. Approximately 90% of this is cost for fuel. Adjust based on increased fuel cost to estimate 1980 cost

$$3.00 \times \frac{1.0}{0.4}$$

Assume average of 5 hr/day operation.

7.5 x 5x5x52 = $10,000/year

Assume $2,000/year for pick-up

Total direct operating cost = 10,000 + 2,000 = $12,000/yr

Major Maintenance

Assume major maintenance is approximately one half of initial capitol cost spread over life of unit.

$$\frac{136{,}000 \times 0.5}{5} = \$14{,}000/\text{year for loader}$$

Assume $600/yr for pick-up

Total major maintenance cost = $15,000/yr

Utilities

Assume $2000/year

Labor

Assume 2 employees paid at $4.50/hr.

Assume 18% fringe benefits and 13% personnel overhead.

Annual labor cost = 2x4.50 x 8x5x52 x (1+0.13 + 0.18) = $25,000/year

Major Excavation

1979 cost for major trench excavation by outside contractor was $14,000. Assume 10% increase for 1980 excavation.

$14,000 x 1.1 = $15,000/year

GARBAGE COLLECTION SYSTEM COSTS

Labor

The Aiken collection workers are presently paid at the following average rates:

Drivers - $4.38/hr

Walkers - $3.43/hr

Assume 18% fringe benefits and 13% personnel overhead to calculate per day labor costs.

Drivers - 4.38 x 8 x (1 + 0.18 + 0.13) = $45.9/day

Walkers - 3.43 x 8 x (1 + 0.18 + 0.13) = $35.9/day

Collection Equipment

Life cycle cost estimate for 20-cu. yd. rear load and side load packer vehicles are given in Table B.1.

Average daily cost = $\frac{19,300}{52 \times 5}$ = $74/day

COMPOSTING COSTS

Note: Many of the facts and assumptions used in this estimate of composting costs were taken from or based on a recent estimate for a 10 dry ton/day facility presented in:

"Windrow Composting Analysis For a Ten Dry Ton Per Day Plant"

By: Lester Haug, Consulting Engineer, March 19, 1980

Assume facility for Aiken is 12 wet ton/day

Equipment

Composter

Assume one composter. Use type of unit which forms and turns windrows.

Total hourly ownership and operating cost for $180,000 model = $45.8/hr (Haug).

Total hourly ownership and operating cost for $120,000 model = $35.8.

Use lower cost since Aiken would process less waste.

TABLE B-1

LIFE CYCLE COSTS - 20 CU-YD REAR LOAD AND SIDE LOAD PACKERS

Year:	1	2	3	4	5
Capital Investment and Depreciation:					
Trade-in value (% of delivery price)	75	55	40	30	25
Investment, start ($)	41,000	30,750	22,550	16,400	12,300
Year-end value ($)	30,750	22,550	16,400	12,300	10,250
Yearly capital cost ($)	10,250	8,200	6,150	4,100	2,050
Debt Service and Insurance:					
Average yearly worth	35,875	26,650	19,475	14,350	11,275
Yearly debt cost @ 12% ($)	4,305	3,198	2,337	1,722	1,353
Maintenance:					
Yearly estimate (% of delivery price)	4.5	6.5	10.5	16.5	22.5
Yearly estimated cost ($)	1,845	2,665	4,305	6,765	9,225
Fuel & Oil ($)	3,000	3,000	3,000	3,000	3,000
Downtime:					
Availability factor (%)	95	94	91	88	85
Hours not available	83	100	150	200	250
Cost @ $10/hr	830	1,000	1,500	2,000	2,500
Reserve vehicle					
Productivity Loss due to Age:					
Productivity factor	98	96	94	92	90
Extra hours required to match					
Production of new model	33	67	100	133	166
Cost @ 10/hr	330	670	1,000	1,330	1,660
Total Annual Cost ($)	20,560	18,733	18,292	18,917	19,788
Cumulative Vehicle Cost ($)	20,560	39,293	57,585	76,502	96,290

Average Annual Cost = 96,290/5 = $19,300

Loader

Total hourly ownership and operating cost for $90,000 model = $25/hr (Haug).

Note that cost is less than Aiken landfill loader because landfill accessories are not required. Size of loader is not specified.

Building

Assume building with sheet metal roof, no sides, no floor, no utilities.

Assume unit cost = $6/sq ft (Haug).

Building for 10 dry ton/day at 20% solids is 50,000 sq ft (Haug).

Assume building size required is proportional to initial quantity of waste.

$\frac{50,000}{10/0.2}$ = 1,000 sq ft/wet ton

Building for 12 wet ton/day

12 x 1,000 = 12,000 sq ft

12,000 x 6 = $72,000 capital cost

Annualize cost over 20 years at 10%/yr

$$\frac{72,000 \times 0.10\ (1 + 0.10)^{20}}{(1 + 0.10)^{20} - 1} = \$8,500/yr$$

Labor

Assume $5.00/hr with 13% personnel overhead and 18% fringe benefits.

Assume one person for 4 hr/day, 365 day/yr

5 x (1 + 0.13 + 0.18) x 4 x 365 = $9,600

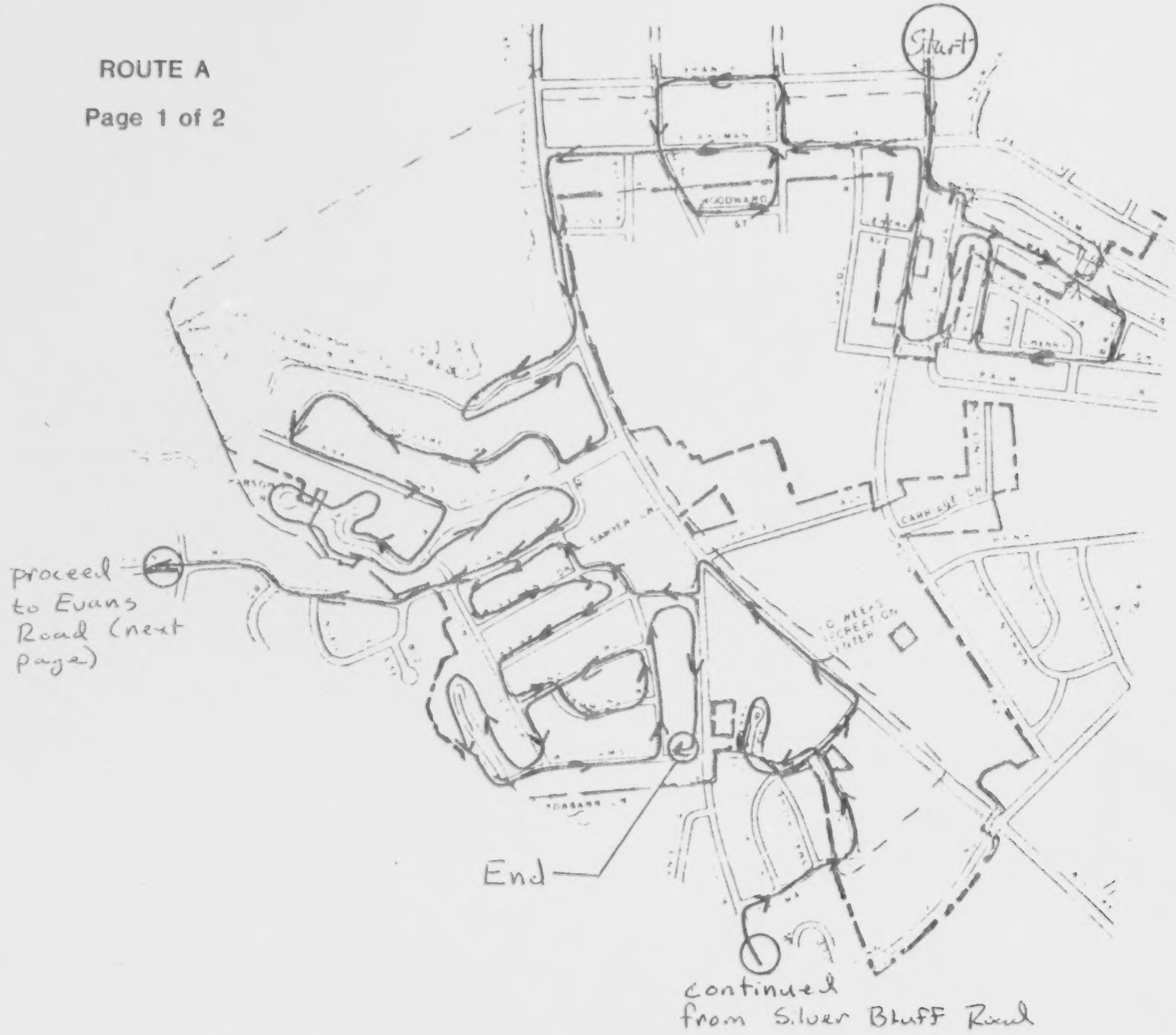
Total Compost Cost Estimate

Composter (3 hr/day; 365 day/yr)	$39,200/yr
Loader (1 hr/day; 365 day/yr)	9,100
Building	8,500
Labor	9,600
Total	$66,400
Unit cost (12 wet ton/day; 365 day/yr)	$15/wet ton

APPENDIX C

COLLECTION ROUTES

ROUTE A


Start
proceed to Evans Road (next page)
End
continued from Silver Bluff Road

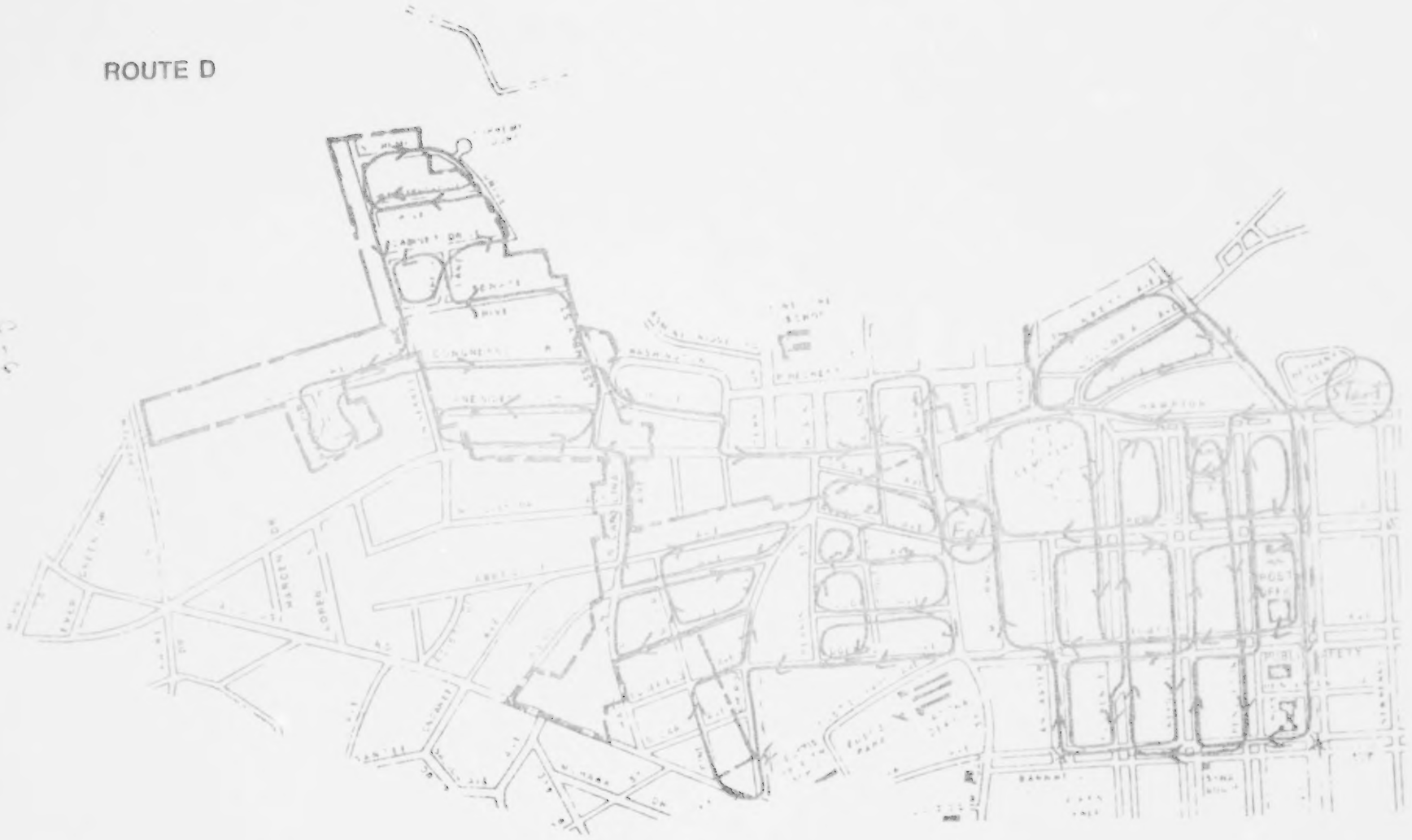
ROUTE A

Page 2 of 2

ROUTE B

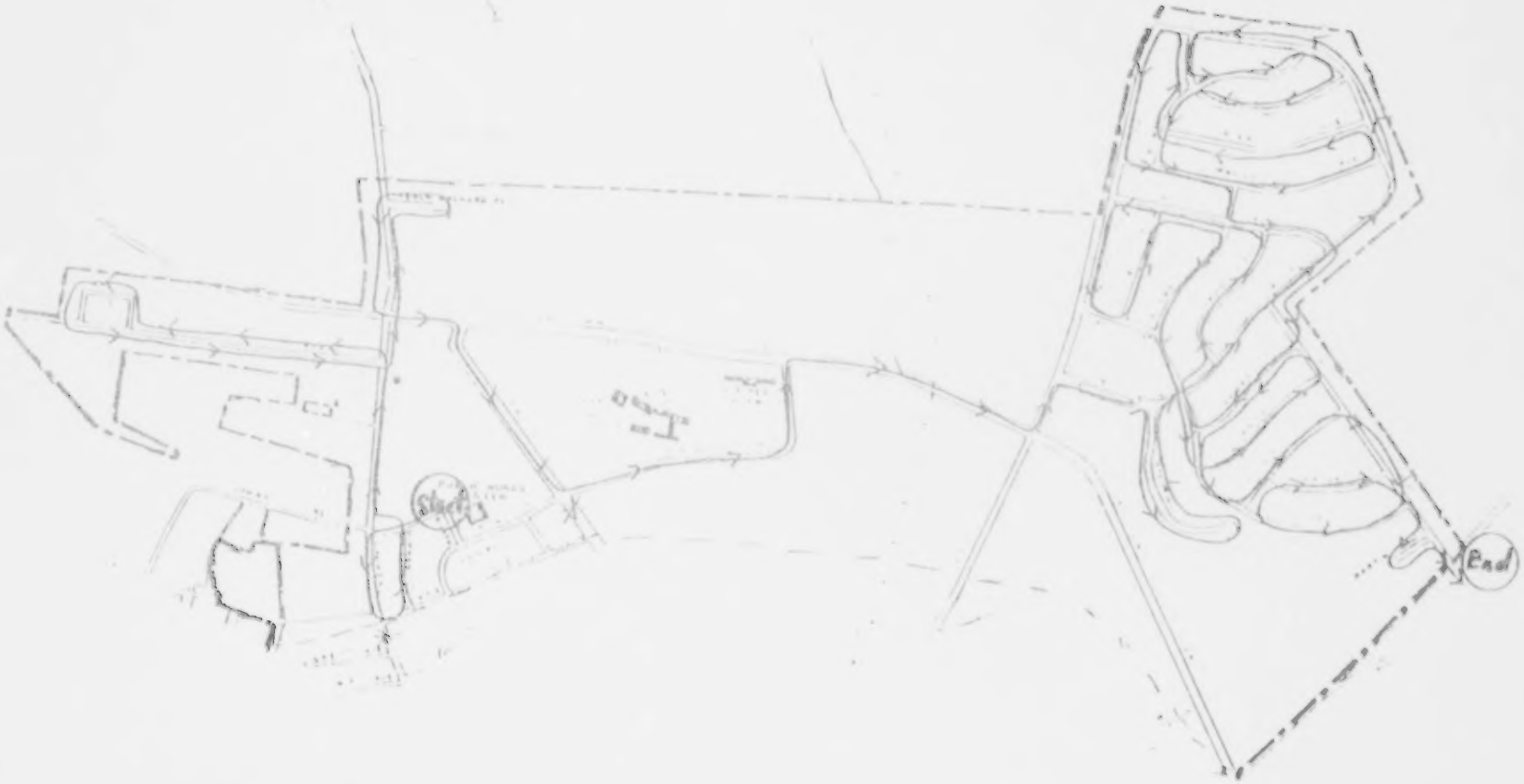
ROUTE C

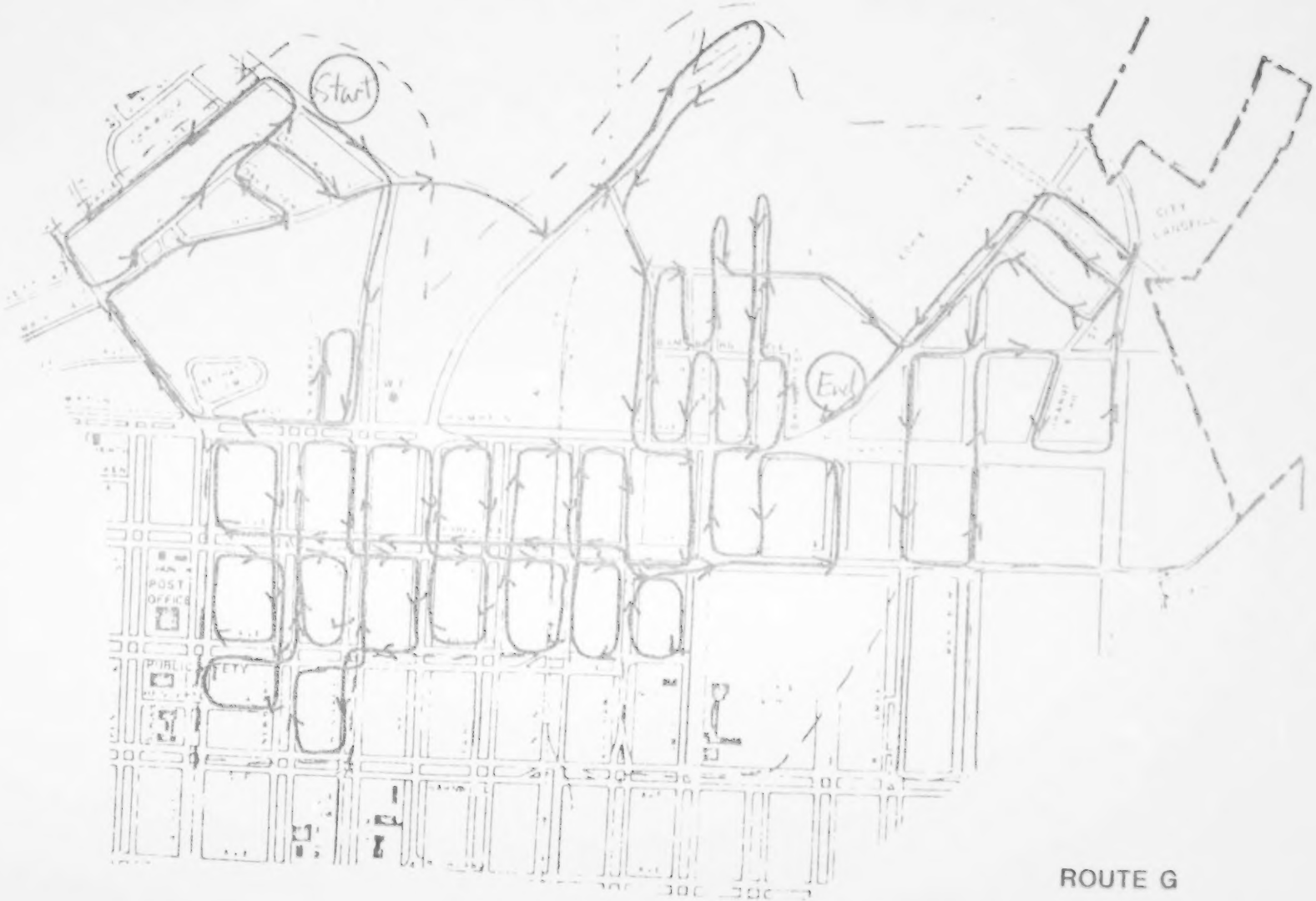
ROUTE D



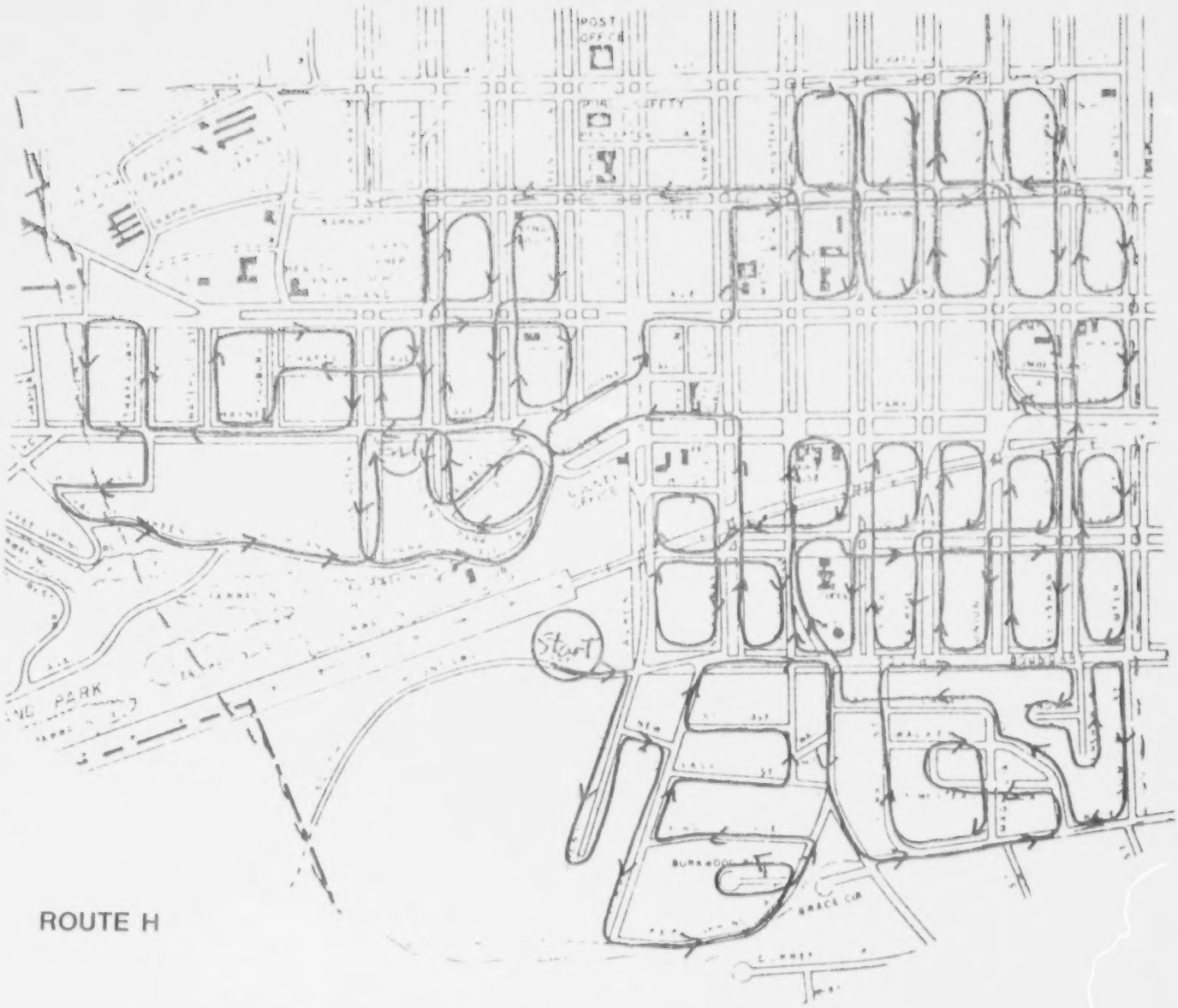
ROUTE E

ROUTE F





ROUTE G



ROUTE H

APPENDIX D
LANDFILL LIFE ESTIMATES

ESTIMATE 1

The objective of this section is to present an estimate of the remaining life of the Aiken City landfill using present operational methods. The estimate and related information are tabulated in Table D.1. The estimate is based on the following assumptions:

- Assume a refuse production rate of 4.3 lb/person-year, 7-day basis (see Appendix B).
- Assume in-place refuse density of 800 lb/cu yd.
- Assume the city's 1980 population is 15,000.
- Assume 10% per year population increase.
- Assume landfill area utilization of 13,000 ton refuse/acre (based on idealized model similar to the one shown on Figure 2.9 with fill average of 25 ft below grade, 6 ft above grade).
- Assume landfilling in unused area shown on Figure 2.5 only (12 acre).
- Assume an average 50-ft buffer zone will be maintained between landfilled refuse cell and border of permitted area (about 2500 linear ft; 3 acres).

TABLE D.1

ESTIMATE OF REMAINING LIFE OF AIKEN CITY LANDFILL USING PRESENT METHODS

Years from Present (1980)	Estimated Aiken Population	Total Waste Production (tons)	Cumulative Waste Landfilled (tons)	Cumulative Landfill Area Utilized (acre)
1	15,000	11,800	11,800	0.9
2	16,500	12,900	24,700	1.9
3	18,200	14,300	39,000	3.0
4	20,000	15,700	54,700	4.2
5	21,000	16,500	71,200	5.5
6	24,200	18,000	89,200	6.7
7	26,600	20,900	110,000	8.5
8	29,300	23,000	133,000	10.2

APPROXIMATELY 7-8 REMAINING YEARS AS OF SUMMER, 1980

ESTIMATE 2

The objective of this section is to present an estimate of how the Aiken City landfill's life can be extended based on the following life increasing concepts.

- Increased area utilization efficiency resulting from alternate landfilling methodology
- Further use of under-utilized portions of the permitted landfill property
- Re-permitting and use of the non-permitted portion

The estimate is tabulated in Table D.2. The estimate is based on the following assumptions.

- Assume a refuse production rate of 4.3 lb/person-year, 7-day basis (see Appendix B).
- Assume in-place refuse density of 800 lb/cu yd.
- Assume the city's 1980 population is 15,000.
- Assume 10% per year population increase.
- Assume landfill volume utilization efficiency of 520 ton refuse/acre-ft (based on idealized model of improved cell structure shown in Case B, Figure 2.9).
- Assume landfilling in remaining 9 acres of Area 1; Figure 2.4. Landfill average of 25 ft below grade and 15 ft above grade (360 acre-ft available).
- Assume additional 10 ft of landfilling in Acres 2, 4 and 5; Figure 2.4. Total acreage of areas is about 16 acres. Deduct 2 acres for buffer at propery line (140 acre-ft available).
- Assume re-permitting and landfilling in the burning area shown on Figure 2.2. Available area about 6 acres (allowing for 50-ft buffer at property boundry). Landfill average of 25 ft below grade and 15 ft above grade (240 acre-ft available).
- Assume no further landfilling in landfill area of non-permitted property (see Figure 2.2) due to possible leachate problems.

TABLE D.2

ESTIMATE OF REMAINING LIFE OF AIKEN CITY LANDFILL USING LIFE INCREASING CONCEPTS

Years From Present (1980)	Estimated Aiken Population	Total Waste Production (tons)	Cumulative Waste Landfilled (tons)	Cumulative Landfill Volume Utilized (acre-ft)
1	15,000	11,800	11,800	23
2	16,500	12,900	24,700	48
3	18,300	14,300	39,000	75
4	20,000	15,700	54,700	105
5	21,000	16,500	71,200	137
6	24,200	18,000	89,200	172
7	26,600	20,900	110,000	212
8	29,300	23,000	133,000	256
9	32,200	25,300	158,000	304
10	35,400	27,800	186,000	358
11	38,900	30,500	217,0000	417
12	42,800	33,600	251,000	483
13	47,100	37,000	288,000	553
14	51,800	40,700	329,000	632
15	57,000	44,700	374,000	720
16	62,700	49,200	423,000	813

Total Acre-Ft Available = 740

Remaining Usable Life = 15-16 yr